CHAUTAUQUA
LITERARY AND SCIENTIFIC
CIRCLE

C L S C

THE GREAT WORLD'S FARM

SELINA GAYE

The Great World's Farm

BY

SELINA GAYE

AUTHOR OF

"THE WORLD'S LUMBER ROOM," "COMING," ETC.

By Permission of The Macmillan Co.

"The world is one vast garden, bringing forth crops of the most luxuriant and varied kind, century after century, and millennium after millennium. Yet the face of Nature is nowhere furrowed by the plough, no harrow disintegrates the clods, no lime and phosphates are strewn upon its fields, no visible tillage of the soil improves the work on *the great world's farm.*"

H. DRUMMOND, "*Tropical Africa*"

NEW YORK CHAUTAUQUA SPRINGFIELD CHICAGO

The Chautauqua Press

MCMII

The Lakeside Press, Chicago, Ill., U. S. A.
R. R. Donnelley & Sons Company

CONTENTS

PREFACE

This edition of the Great World's Farm has been somewhat abridged from the original English edition in order to bring it within the limits required for books of the Chautauqua Reading Circle. No essential features of the work, however, have been eliminated, and the chapter divisions remain the same as in the larger edition, with the exception of the last, "Man's Work on the Farm," which has been omitted entirely.

"Readers of mature years can hardly fail to find in this volume some facts that are new to them, some suggestions of a wider interpretation of nature or of a more accurate perception of its interrelations, or some fresh cause for intelligent wonder."

THE GREAT WORLD'S FARM

CHAPTER I

INTRODUCTORY

What would the learned writer of the old Eton geography of sixty years ago say to the statement that the whole earth is one great farm or garden, almost everywhere covered with vegetation, and "bringing forth crops of the most luxuriant and varied kind"? This was certainly very far from being his own idea, for he informed his students that at least one of the "quarters" of the world was little more than "a vast, sandy desert."

Such was his description of the great continent of Africa, where, according to him, there was no cultivation except in the immediate neighborhood of a river or spring, "all the rest being one wide tract of utter desolation"; and he went on to say: "These cultivated places, appearing like islands or oases in the great desert, caused some of the ancients to compare the whole continent to a panther's skin, dotted, as it were, with spots of fertility surrounded by a brown and burning desert."

As a matter of fact, nothing could "more wildly misrepresent the truth" than this description; but it was written before the interior of Africa had been explored, and the old geographers, feeling, it would seem, obliged

to say something, were very much in the habit of writing "desert" across those regions of the earth which were to them "unknown."

These imaginary deserts, which once occupied so large a space in our maps, are, however, fast shrinking and dwindling away before the face of the explorer, until there are few if any left. The last so-called desert in America was that to the west of the United States, and that vanished some five and twenty years ago, when Mr. Hepworth Dixon said of it: "It has retreated further and further, and has taken its last stand behind the Missouri, where I faced it, and now I can assure you that I have been right through the Great Prairie, and desert there is none. The prairie is the pasture-land of the world—already prepared; that is, to afford an ample livelihood to man's flocks and herds as soon as he should choose to make use of it; and certainly, therefore, no desert, though "only an Indian hunting-ground!"

But still, it may be said, there is a wide difference between a desert and a farm. If the prairie is not bare, at least it is uncultivated; and the word "farm" suggests the idea of plows and harrows, orderly crops, sheep, and cattle. Very true; but because nature farms in ways of her own, on a large scale and without fuss, while man farms in his way on a small one, and lets all the world know what he is doing, is that any reason for denying to nature the name of "farmer"?

How much of the earth has man brought under cultivation? In Europe, where he has done most, the proportion varies from little more than a twentieth (in Sweden), to a little more than one-half (in Belgium). Supposing that he farms, or "improves," one-tenth of the land all

the world over—and he certainly does not do more at present—what becomes of the other nine-tenths? It is not a desert, it does not lie idle; with but few exceptions, indeed, it is covered with crops of one sort or another; for the world is a green world, not a brown one.

But where crops are grown century after century, millennium after millennium, no matter whether they be wild or not, there must needs be tillage, and that of the most thorough kind, fully deserving the name of farming, though it may be carried on without steel plows, and so quietly as to escape our notice.

There are vast pasture-lands here, there are extensive forests there; there are woods, jungles, heaths, moors, downs, but they have all been planted; and the soil was prepared in the first instance, and has been renewed since, by laborers who are not less truly deserving of the name of laborer than the plowman, though they do not work with his implements.

When Captain, afterwards Sir, Francis Head, traveled nine hundred miles across the Pampas, he saw to his surprise, first, one hundred and eighty miles of the most luxuriant clover and wild artichokes; then an unbroken stretch of long grass, four hundred and fifty miles wide, without a weed; and finally, growing up to the base of the Cordillera, a grove of low trees and shrubs.

Man had had no hand in preparing the soil for this grass and clover; man had neither sown them nor cared for them in any way: yet there they were, just as good food for his cattle as if they had been grown on the most orderly of human farms. Surely, then, the lands of the Pampas had been "farmed" most successfully, by one means or another. For the word "farm" is said to be

derived from an Anglo-Saxon verb which means "to supply with food," and certainly, in this sense, the lands which man still leaves to nature's laborers have every claim to be considered as one vast farm; for they grow, many of them, the most luxuriant crops, and they feed more live-stock than can be numbered.

Man grows, for himself and his live-stock, a few vegetables—about two hundred and fifty species—and he has adopted, and partly domesticated, about two hundred animals. But on the great natural farm things are done on a very much grander scale. Here the species of crops grown number not much less than a hundred and forty thousand; and the different species of live-stock amount to some millions.

With so many animals to feed, and so many crops to grow, nature's farm-laborers do not allow of "deserts"; and wherever there is an unoccupied surface, they hasten to take possession, and if possible, sow something upon it, if it be but a lichen. They sow even the little heaps of dust which collect in sheltered nooks, on the leads of the church-tower, on walls, in the angles of masonry, and make them bear at least a blade or two of grass, and often quite a crop of various green things. Generally speaking, it is only by recent lava-fields, and the loftiest, bleakest peaks of rock, that these energetic laborers are baffled, and then it is only for a time.

Over and over again, as Mr. Ball says, he was told in different parts of the world that such and such a spot was entirely devoid of vegetation; or in other words, a desert; and over and over again he found it to be quite a mistake. On the so-called "bare" peaks of the Dolomite Mountains he always found a "fair number" of plants

hidden in cracks and crevices; even at Suez, on the exposed, burnt-up face of the mountain Djebel Attakah, he still found something, and in the northern part of the Great Sahara, though vegetation was scanty, it was difficult to find many yards together that were actually bare.

In fact, Mr. Ball had come to doubt the existence of "deserts" altogether by the time he reached the "rainless zone" of Peru, and was once more told that he would find no vegetation at all. Certainly this was more barren than any part of the world which he had yet seen, except indeed the drifting sands above Cairo; yet even here there were plants, stunted bushes in the gullies, and tiny vegetables in the depressions where the scanty rain rests longest; but they wanted looking for, as there was scarcely one so much as three inches high. The laborers had done their best; they had prepared the soil, and they had sown, but they had been hindered from growing anything like a luxuriant crop by want of water. And at one place, Tocopilla, they had been entirely baffled; for here at last Mr. Ball found his desert—an altogether barren spot, where not a single green thing was to be seen, and not so much as a lichen was to be discovered, even with the help of a microscope.

But this is quite an exceptional state of things, due to the extreme rarity of the rain; and such utterly barren surfaces are not only very few, but very small, compared with the whole extent of the farm—mere spots, in fact, in the midst of generally luxuriant crops.

In most cases the so-called deserts are deserts only for want of water; the soil has been carefully made ready, and in the Great Sahara and the deserts of Egypt it is extremely rich, though at present covered with sand.

What it might be, and how easily it might be made to "blossom like the rose," we can to some extent guess, when we find that the passing showers, which are all that visit the deserts of Egypt, are sufficient, scanty as they are, to awaken "the green things on the yellow surface"; though we may well wonder how the seeds "could germinate after months of exposure to the burning sun."

And then, again, while it is quite certain that such vegetation as exists in these regions is grown entirely by the natural laborers, there seems also good reason to suppose that man actually does much to hinder their work.

If, for instance, man and his domestic animals were banished from the Arabian and African deserts, it is believed by Mr. Marsh that many parts of them would soon be covered with forests, and with forests would come rain, to the enormous benefit of the whole region. Acacias of several species are constantly being sown, and they sprout up plentifully around the springs and winter watercourses, while grasses and shrubs grow up under their sheltering shade. But these latter are mown down as fast as they grow by the hungry cattle of the Arabs; and even the trees do not escape, for the goat devours the seedlings whenever it has the opportunity, and the camel will bite through thorny branches as thick as the finger, and unfortunately it has a particular liking for the twigs, leaves, and seed-pods of the acacia; so that between them, the tree of the desert has but little chance. If only they were left undisturbed for a few years these spots would be covered with groves, which would gradually extend where now little can grow but the foxglove and colocynth.

Still, even now, these deserts cannot be called bare,

though their crops are scanty. As we have said before, the laborers on the great farm do not allow any surface to be bare, if they can help it, and they work as if it were their one object to grow as many crops as possible. The very snow-fields and ice-fields are not allowed to lie idle, for there is soil even here, and it must not be wasted.

Dust, meteoric dust from the higher regions beyond our atmosphere, is constantly falling all over the earth, to the amount, it is believed, of more than five hundred thousand tons every year; and though being scattered evenly over the whole surface, it must be spread very thin indeed; still, where there is no other mineral matter, as on the snow and ice fields of the Arctic regions, it is quite perceptible, and it is enough for the growth of such humble vegetables as the "Red Snow," which in summer covers the white surface with a flush of rose color many miles in extent. Nor are this and other similar minute plants grown to no purpose. These "barren fields" are also part of the great world's farm, an outlying part, it is true, where the produce is not large; but such as they are, the crops are needed, for there are glacier-fleas and other live-stock even here, and these tiny vegetables supply them with food.

Nature's laborers are such zealous and thrifty husbandmen that they are always on the watch to occupy every inch of space where anything can be grown the moment it is vacated, and even before. They will overrun our gravel paths, and grow grass in our streets if allowed, and they will take but a very short time to convert the most highly cultivated garden into a wilderness without any trace of a path in it, if it be given up to them. This is true even in such temperate climates as our own, but in

warmer latitudes the incessant struggle of the wild crops to invade and recover the ground which they have lost is still more marked.

At Pará, in Brazil, for instance, we are told that every lane, yard, and square is a battle-ground. Even the roofs and cornices of some of the public buildings are occupied by plants or small trees, which wave their feathery heads aloft like flags of triumph in defiance of the enemy. The city is hemmed in by a wall of tropical forest, consisting of giant trees, palms, and tangled creepers, which ever and anon send out skirmishers to try and effect a lodgment in the enemy's territory; and so well do they succeed where circumstances favor them, that a large square, which was cleared and turfed, but left unguarded, was covered in five years' time with a tangled mass of vegetation fifteen feet high, and denser than the virgin forest.

For there is no lack of laborers on the great farm. They are employed by the million in all parts of it, and though they are always ready to reclaim any portion which has been taken from them, they nevertheless attend impartially to the whole—the small part which man has taken under his own care, as well as that which he leaves at present entirely to their management.

And a very sorry condition the human farmer's fields would be in if they were left to himself alone, in spite of all his improved modern appliances and scientific knowledge.

"It is an easy error to consider that he who has tilled the ground and sown the seed is the author of his crop." And for the most part, perhaps, the farmer realizes but little of the vast debt which he owes to the unseen, un-

noticed, and often abused, laborers who are incessantly at work for him.

Of course, he knows very well that he cannot do without sun and rain, and he will readily allow that dew, frost, and wind are useful, and that at present he could hardly do without them; but grant him these—and what are they after all but laborers borrowed from the larger farm—and surely his improved plows and harrows and his patent manures will be able to manage the rest. In the days when a forked stick was the best plow, no doubt things were different, and the farmer was more dependent upon what the natural laborers were pleased to do for him, but now!

Well, let him try! There is an island just risen above the waves here, or there is a stream of cooled lava there—nice, fresh, virgin surfaces both of them, where nature's husbandmen have not yet been at work, so that he may keep either to himself, and show what he can do when he is not interfered with. Let him try his modern steel plow, driven by steam, too, if he will, upon either of these.

But there is no soil! Of course not; is the soil put ready for nature's laborers? Do they not have to make it, and out of these, or similar materials? But one cannot plow the bare rock, even with the help of steel and steam; and before these can do anything with it, it must be broken up and crumbled by other workers, much more humble and feeble in appearance, most of them absolutely noiseless, some quite invisible, and yet—far more powerful.

Wonderful things, no doubt, are being done with machinery, and the time may possibly come when we shall be able to grind up the rock without too great

expenditure of time and labor; but even then, powdered rock is not soil, and will not grow any crop worthy of the name. It must be mixed as well as pounded before it can be converted into fertile soil, such as the farmer will find it worth his while to cultivate. And who is to mix it? It will not pay him to attempt the work himself on any large scale; but it has been done, and is constantly being done, on all parts of the great natural farm.

On the whole, then, the farmer will probably find it best, at least for the present, to accept what has been done for him, and to cultivate the soil which he finds ready made.

"Ready made?" but doesn't he still have to plow it, and harrow it, and manure it? To be sure; but this is no more than has to be done, and is done, by the natural husbandmen also all the world over. Crops cannot be grown year after year, for many years in succession, without constant labor. For every crop takes something from the soil, and the loss has to be made good. The clods must be broken up, too, or the air and rain cannot enter freely, and the roots cannot make their way through the soil. And this the farmer must do as best he can, with his plow and harrow; but these are at best only clumsy instruments, and they are not enough by themselves. If the fields were deserted by the "natural plowmen," the worms, and others, the farmer would speedily find that his plows could accomplish only the rough part of the work. And it is much the same with the harrows; they cannot do the fine work of the great "natural harrow," the frost, which crumbles the soil, grain by grain, till it is reduced to the condition of dust and ashes, ready for sowing.

And now surely the farmer may put in his seed and feel that if only seasonable weather be granted him he may be quite independent of further help from his humble fellow-laborers. The "if," to be sure, is rather a great and important "if," and altogether beyond his own control; but granted the weather, may he not go on and prosper?

Not unless he is prepared to pay a whole army of boys to keep off marauders; and even then he would probably find himself worsted in the battle with slugs, and snails, and grubs, for these creatures have an especial fondness for seedlings, wild and cultivated. We are told, for instance, by the Rev. F. Morris, that out of five hundred and four grains of rape planted as an experiment, two hundred were eaten or injured. And how many even of these would have escaped if "nature's militia," the army of birds, had withdrawn their services? Very few, probably, for the farmer has not yet invented any satisfactory substitute, and if he be wise he will certainly welcome them in his fields, and be glad that they do not limit their care to the wild crops of the farm.

But when the crop has escaped these serious perils and dangers, what then? Even then the farmer will not in many cases have any harvest, unless nature again comes to his help and lends him a fresh set of workers different from any hitherto employed in his service. This is especially true of the fruit-farmer and the market-gardener. The orchards and gardens may be a mass of blossom, but if they are left to themselves at this critical time there will be few apples, strawberries, or raspberries, and absolutely no melons or cucumbers, no matter how favorable the weather may be. And the same holds good with regard

to many another crop. Help is needed if they are to bring their fruit to maturity, and this help the grower is, generally speaking, quite unable to give; that is to say, he may be able to give it here and there in a few instances, but he would be powerless in an orchard, and would not be able to afford the time necessary to do the delicate work required in a single strawberry bed. Again, therefore, he must look to nature's laborers for assistance.

Take the following example, for instance: In his garden at Santo Domingo, Nicaragua, Mr. Belt, the naturalist, sowed some scarlet-runner beans. The soil was good, and the climate was favorable to bean life, and the scarlet-runners grew and flourished, and finally blossomed abundantly.

But it was finally! for here their career ended. They did not produce a single bean among them, simply because the right laborers were not at hand to give the requisite help.

The garden in which the beans grew had been recently taken from the forest, by which it was still surrounded; and that the laborers in this part of the farm were not idle was quite evident from the abundant luxuriance of the vegetation. But it was tropical vegetation, and as it did not include scarlet-runners, these were in the position of foreigners, whose appeals for assistance were not understood. It was in vain they put forth the bright flowers, which were well-known signals in their native land, and would there have brought them the helpers they needed—no one noticed them. They were made welcome to the soil, the rain, and the sunshine, and then they were left to themselves and their master, with the result already mentioned—no fruit!

And who were the gardeners whose absence proved to be of such vital importance? Humble bees, only humble bees! and indeed, only the particular species of humble bees which wait upon scarlet-runners. There were plenty of others, but they did not understand, though very probably they would have come to do so in the course of a few seasons. As it was, however, failing these insect laborers, there was nothing to be done—nothing to take their place. Man has not yet discovered any substitute for the bee.

In the following chapters we shall consider in more detail the various ways and means by which the work of the great farm is carried on by the natural laborers, and also some of the changes made in it by the work and unconscious influence of man.

QUESTIONS FOR REVIEW

1. How have our ideas of the fertility of the earth been changed in recent years?
2. What proportion of the earth in Europe has been brought under cultivation?
3. How do the animals and vegetables used by man compare in number with nature's supply?
4. Show how nature makes use of every possible opportunity for raising crops.
5. How do man and his animals sometimes help to increase the desert regions?
6. Show how the farmer is dependent at every step upon nature's laborers.

CHAPTER II

PIONEER LABORERS

No one needs to be told that all living things require food of one sort or another to keep them alive; but some people have fancied, even within the last hundred years, that vegetables had such delicate appetites as to need nothing but air and pure water for their sustenance. As a matter of fact, however, no vegetables live upon a diet of mere air and water.

But then, what of the seaweeds which float about in the ocean? Are there not vast meadows of weed far away from soil or even rocks of any kind? Does not the ocean, moreover, swarm everywhere, from the polar regions to the equator, with microscopic vegetables? And is it not a fact that no seaweeds, not even those which cling to the rocks, receive any of their nourishment through their roots, and therefore must live upon water? Quite true that they do not feed by means of their roots—indeed, no seaweeds possess true roots; and it is quite true, also, that they live upon what they obtain from the water, but surely the taste of it is sufficient to prove that it is not mere water.

There is no such thing as pure, absolutely pure, water in nature; and sea-water, which is much heavier than fresh water, contains thirty-five parts of solid matter in every thousand. The rivers are constantly pouring into it small quantities of every sort of mineral substance that

can be dissolved, while the sun draws up from it almost pure water, leaving the salts behind to accumulate and help to feed the crops of seaweed, besides providing material for the skeletons of corals and sponges and the shells and bones of other sea-creatures. All plants, then, are alike in this, that they live upon other food besides mere air and water.

We may easily satisfy ourselves of this by burning a bit of wood, a few grains of corn, or any other vegetable matter. When it has burned as long as there is anything to burn, and all gases and water it contained are driven away, a small quantity of ash will remain, consisting of salts, or compounds of various metals. The whole amount is usually very small—so small that we might perhaps be disposed to think it could not be of any very great consequence.

If, for instance, we were to burn a hundred grains of wheat so thoroughly that nothing but ash remained, we should find the whole amount of this to be equal to about two of the grains, or less.

However, "many a mickle makes a muckle," and when we consider, not single plants or a handful of grain, but a whole crop, the amount of mineral matter becomes large enough to look important. Thus, while a pinch or two of dust might represent the entire amount of ash of all sorts in a single turnip or carrot, there are, on an average, about forty pounds of lime alone in twenty-two tons of turnips, more in proportion in the carrots, and very much more in an equal weight of clover.

The mineral substances chiefly taken up by plants are sulphur, phosphorus, silica, potash, soda, lime, iron, magnesia, manganese, together with mineral compounds

of the two gases chlorine and fluorine. All these are contained in the rocks; but as long as it is stored in the rocks it might as well be locked up so far as most of them are concerned, for they cannot get at it or make use of it. The stone must be converted into soil before they can turn it to account; and how is this to be accomplished?

If a man had to make his soil from the rocks before he could grow his crops, he would have to begin with crowbars and pickaxes, if he did not first resort to blasting with gunpowder or dynamite, and even then his progress would be slow and laborious.

Nature usually works in a much more quiet and unobtrusive fashion, but there are times when she, too, has recourse to blasting as a preliminary measure. She mines the rocks and shatters them by means of the earthquake, compared with which the power even of dynamite is insignificant; but it is the noiseless and often invisible workers who accomplish most, for they are at work, some or other of them, incessantly during every moment of every hour, day and night, summer and winter, throughout the whole year.

Usually the first of the silent laborers to begin work upon the rocks are also the invisible ones—the gases of air and water, which wear away the very hardest rocks by degrees.

The two gases which do the chief part of the chemical work are oxygen and carbon dioxide, formerly called carbonic acid. Rocks containing much iron are especially open to the attacks of the one, and those containing lime, potash, soda, to the attacks of the other. We are all familiar with the fact that iron and steel become covered

with rust if left exposed to the air. Keys rust if left in their locks, and even polished fire-irons often rust in the summer, unless they are oiled or greased, and so protected from the air. What happens in these cases is that the oxygen, always present both in the air itself and in the watery vapor floating in the air, lays hold of the metal and combines with it to form a compound substance—an oxide—which is looser and softer, and takes up more room than the metal alone. At first the rust is a mere reddish brown stain; but as the oxygen eats deeper and deeper, and more and more oxide is formed, it swells up unevenly above the surrounding surface, and feels rough to the touch. It is so soft that it may be partly rubbed off by the finger, and when the rust is cleaned away there will be scars and indentations left, showing how much of the metal has been removed.

Very many rocks contain iron, as, for instance, the slates, sandstones, granites, and basalts, some more, some less, but hardly ever in a pure state. The basalt of the Giant's Causeway contains so much iron that, on those sides which are most exposed to the weather, it not only looks rusty, but is also softer on the surface and less compact within, for nature's laborers do not generally work singly and alone, but in union one with the other, and the great ally of oxygen is moisture.

Let us take basalt as an example, and see how this rock is crumbled into soil. In perfectly dry air, at the ordinary temperature, oxygen is powerless to do even so much as tarnish iron in the mass, though it would have no difficulty in reducing it all to oxide—that is, rust—if the same mass of iron were exposed to its action in the form of powder. Fire-irons do not rust in winter, or

when in constant use, because the fire keeps them dry; they do rust when unused in summer, because natural air is never perfectly dry, even on the driest summer day, not even in the midst of the parching desert.

But if iron quickly rusts when exposed to the damp air of such a climate as ours, we all know how much faster it does so when actually wetted; and therefore it is not surprising to find that basaltic and other rocks containing much iron decay more rapidly on the side which faces the rainiest quarter—not that the force of the rain makes so much impression on them as on softer rocks, but that the wet enables the oxygen to work faster. The decay is not confined to the surface, moreover, for all rocks, even those which are most close and compact and are called impervious, absorb some amount of moisture, and this also finds entrance through the cracks and joints, from which no large mass of rock is ever entirely free. These joints are especially well developed in the basalt—an ancient lava—which, in cooling down from the molten state, has shrunk and contracted into columns having from three to nine faces, and measuring from a few inches to several feet across. The rain, of course, easily finds its way in between these columns; but patches of wet and brown stains are also found actually inside the columns themselves, when these are broken open, showing that moisture has been sucked up by the rock.

Now water in the natural state always contains some amount of air dissolved in it, and wherever the water penetrates, there the oxygen of the air penetrates also, and lays hold of any iron that comes in its way, as we see by the stains that it has done in this instance.

The iron of the basalt is not, indeed, pure iron, being

already combined with some amount of oxygen, but it does not acquire the reddish brown color of what we familiarly call "rust" until it has absorbed as much oxygen as it can hold. In this condition it is, of course, heavier, and as we have seen, softer than before, and is therefore more easily washed or blown away from the surface. But it is also more bulky, and takes up more space than it did before, so that if it be formed inside the rock where it has not room to expand, the rock is cracked by it. This, of course, opens the way for more water and more oxygen to enter, and so the work proceeds, and the decay goes deeper and deeper.

We have chosen iron-rust as a sample of the way in which oxygen works because it is one of which we all know something, but it must not be forgotten that this is only one of many oxides formed in the rocks; and that whenever oxygen combines with any other substance in a rock to form an oxide, it makes that substance take up more room than before, and so the rock is cracked and crumbled. The other gas, carbon dioxide, works in a different way, though it also helps the oxygen to rust iron faster than it could do alone. But when it works on its own account it is by combining with such substances as lime, potash, soda, and magnesia, which it makes much more soluble than they were before.

Some rocks are said to be impervious, or "waterproof," but this only means that they allow water to enter so very slowly that unless they are actually soaking in it for some time hardly any is taken up. Water has some effect upon every known mineral, unless it be perhaps upon gold and platinum. But water in nature is never perfectly pure; how can it be, since it dissolves some,

though it may be only a very minute quantity, of everything through, or over, which it passes? Its dissolving powers are greatly increased, too, by the addition of carbon dioxide—the gas we are now speaking of—which is being constantly produced both in earth and air, by the decay of vegetable matter in the one, and by the lungs of animals, fires, and furnaces in the other.

The rain as it descends from the clouds washes down with it some of this gas, and if it comes in contact with such a rock as limestone, soon makes an impression upon it. Chalk, limestone, and marble are all composed of carbonate of lime, softer or harder, the lime being already united with a certain quantity of carbon dioxide. But in this condition it dissolves so very slowly as to be called insoluble in pure water. When it comes in contact with the gas, however, whether in air or water, it takes up double the quantity it had before, and is converted into a double, or bicarbonate, which is easily dissolved and washed away.

Even rocks which consist only in part of carbonate of lime are open to the attacks of carbon dioxide. For instance, there are the sandstones. The grains are hard enough, being composed of silica, and if they are cemented together with silica, too, the stone is one of the most durable that can be found, neither water nor gases, together or separately, being able to make much impression upon it. But if the grains are cemented together by iron oxide, or by carbonate of lime, it is quite another matter. Oxygen or carbon dioxide may get to work on the cement, and as that is removed the grains fall apart and become sand.

But nature's laborers proceed upon the principle that

"union is strength," and they so constantly work in company that it is a difficult matter to apportion the results of their labors exactly each to each. We have already seen how water dissolves; we must now look at it in another capacity, and see how it acts the part of crowbar and pickaxe, and even at times of dynamite. A cubic inch of water, when converted into steam, occupies just 1,728 times as much space as it did before, and it expands with such violent force as to shatter the rocks beneath which it is confined. Such explosions as this sometimes occur during volcanic eruptions, water having found its way down through the earth till it has come into contact with some mass of molten lava, which has converted it into steam, and made it a powerful engine of destruction. But water expands also, though in a less degree, when it is converted into ice, and it is under this aspect that we are most familiar with its doings.

Water, as we have said, finds entrance everywhere, more or less, in one way or another, and wherever it is sufficiently near the surface to freeze, there it has the effect of a multitude of crowbars and chisels of all sorts and sizes wielded by an invisible army of workmen. It widens every crack in which it is formed, prizing up large masses of rock many tons in weight, loosening and eventually forcing them off, and also doing finer work, such as chiseling off splinters and particles of all sizes, large and small. The immense piles of rubbish which strew the surface of the glaciers, and consist of sand, grit, and fragments of all dimensions, are due mainly to the action of the frost, which in mountain regions recurs not merely every winter, but every night throughout the year.

But even where there is no rain, and no ice can there-

fore be formed in their cracks and crevices, the rocks themselves feel changes of temperature; and where these changes are sudden, severe, and often repeated, no rock is strong enough to stand against them. The rocks of the Sahara and other similar regions are crumbled into sand simply by the intense heat of the day and the sharp frost at night.

When the Glass Road was being made in the famous Yellowstone Park (Wyoming, U.S.A.), some huge blocks of obsidian, or volcanic glass, were found to come in the way; and as they were too hard to be either hewn or drilled, and could therefore not be blasted, the engineer in charge had large fires lighted on the top. When the rocks were scorching hot, a sudden deluge of cold water was poured upon them from the neighboring lake, and by these means they were thoroughly shattered. This is, of course, a very extreme instance of the effect produced by changes of temperature, and such as would seldom, if ever, occur in nature; but it may serve to show how very real these effects are.

Of the other ways in which the rocks are broken up, it will not be needful to say much. We must pass over with brief mention the work done by sand, set in motion by wind or water, which cuts and polishes the very hardest rocks when driven against them by the former, and when driven by water, has produced the great cañons, or narrow gorges some thousands of feet in depth, with which we are familiar in California.

But a few words must be said about the glaciers, those frozen rivers, which are among the mightiest of nature's grinders. Looking down upon a glacier, and seeing it strewn with the blocks of stone and vast heaps of rubbish

which have fallen upon it from the cliffs above, dislodged by the frost, we should be disposed to think it a very rough laborer indeed, merely engaged in carting away the wreckage made by others. But this would be a great mistake; for the glacier is a giant mill-stone, pressing upon the rocks beneath with a power which is simply irresistible.

Glaciers move on in solemn silence, it may be at the rate of perhaps only an inch or two in the twenty-four hours, but they go on steadily and noiselessly, and as they go, they grind the rocks beneath to a powder so fine, that when at last it escapes from the glacier-mill in the stream, which flows out from beneath, it has been reduced to nothing but mud.

One other grinder, equally mighty and thorough, but by no means silent, must be mentioned in conclusion. This is the volcano, which, besides pouring forth streams of lava, often buries the surrounding country many feet deep in the finest dust and ashes, or in mud, if the eruption be accompanied, as it often is, by rain.

But the laborers which we have been thus briefly considering are only pioneers. They accomplish only the rougher work of preparation, and very much remains to be done before anything that can properly be called "soil" is ready for the crops.

QUESTIONS FOR REVIEW

1. Illustrate the fact that all plants require other food than air and water.
2. Describe the action of oxygen upon iron.
3. What effect has water upon minerals?
4. Show how carbon dioxide works upon the rocks.
5. By what different methods does water break the rocks apart?
6. How are the rocks of the Sahara crumbled?
7. By what agencies are the rocks ground and polished?

CHAPTER III

SOIL-MAKERS

Standing before some bare expanse of hard rock, we might well wonder, if we knew nothing of the subject, how it should ever be converted into a surface fit for the support of vegetation. There may be vineyards close by showing that it has been done in other instances; but what is to be the first step?

If we were to look closely at the seemingly bare surface, we might, and in most cases would, find that it was not altogether bare and barren. We might need a microscope to show us the truth, but if we understood what we saw, we would discover that the rock had been sown.

The pioneer laborers, far from finishing, have hardly begun their work here, but seed has been scattered in this unlikely place; and if we look at what has been done in other similar places, we shall see that it has not been wasted.

Floating about in the air, invisible, but in countless multitudes, are—what answer to the seeds of other plants—the spores of those strange forms of vegetation called lichens, which, except in towns, are to be seen beautifying every old wall, roof, and tombstone. They are so light that they cannot settle at all, except when the air is still, and even then the least breath would disturb them.

But they are sticky, and this stickiness enables them to

cling fast even to the bare rock. Once settled, they begin to grow, and are the first traces of vegetable life to make their appearance upon recent streams of lava. They may truly be called "traces," for the first-comers are nothing more than helpless looking stains, or dust, hardly noticeable except by those on the lookout for them; and one would have said anything but dangerous to the rock, for they look not only perfectly inactive, but entirely lifeless.

The lava has resisted for some time. For years it did not even cool, and it has scorched innumerable lichen spores to death in their attempt to settle upon it. Even when the surface had cooled there was for a long time heat enough within to dry all the life out of them; while multitudes have found the glossy surface too glossy even for their powers of clinging, and have been blown away as fast as they came. There are some streams of lava which are as glossy now as when they were first poured forth three or four hundred years ago, and no lichens have as yet managed to gain a footing there. But they are not generally kept so long at bay. They return to the charge again and again, helped by the pioneers, who have also been at work meantime, and have gradually roughened the surface a little, or at least have taken off some of the glossiness; and at last the spores manage to settle and fix themselves so firmly that neither wind nor rain can dislodge them, and they begin to grow and spread at their ease.

Then, in spite of what was said in the previous chapter, these vegetables, at all events, must live on air and water?

Not at all! Lichens are very substantial feeders

indeed, and consume more mineral matter in proportion to their size than any other plants.

But if it is locked up, and not available until the rock is crumbled down and softened enough for the roots to penetrate into it, how can they get at it?

In one respect lichens are like seaweeds, for they have no roots through which to take up food. But they are unlike them in another, for they do feed upon the rocks; and even these first-comers, the humblest members of the family, mere stains in appearance, contrive to make a living wherever they can gain a footing. Not, of course, that they take up particles of stone, but being all of them strongly acid, they are able to dissolve it first and then absorb what they need; and though they are at first so minute as to be almost microscopic, no rock can resist them.

The "stains" spread and grow and decay, and by degrees there is formed from their remains a thin film of soil, in which lichens of a much larger growth are able to flourish. They are all more or less harsh to the touch; and the ashy, steely grays, and rusty browns, and the brilliant yellow and orange of their coloring remind one more of minerals than of vegetables, which is not surprising, considering that often a fifth part of their substance, and sometimes much more, consists of solid matter eaten from the rocks.

When the lichens have had possession for a time, and have prepared the way, they are followed by mosses, which absorb much moisture from the air, and help to decay the rock by keeping the surface damp; for, as we have already seen, where water is, there frost and gases can get to work. The mosses grow and die in their turn,

and their remains, with those of lichens and loosened particles of rock, as well as the dead bodies of such minute insects as may have found a dwelling among them, together form something deserving the name of mold, which will support plants of quite large size. These are followed by dwarf shrubs, whose roots help on the work more rapidly; and in a century, more or less, the stream of lava is usually converted into soil fit for the planting of vineyards and gardens.

Lichens attack not only lava, however, but also granites, slates, and even hard crystalline quartz-rock, wherever there is sufficient moisture. No rock is proof against them; almost any climate suits them, hot or cold, moist or dry, and they are the last signs of vegetation to be lost sight of by the mountaineer as he ascends towards the region of perpetual snow and bare peaks, whither even they are unable to follow.

The so-called violet-stone, found on the summit of the Brocken, is nothing but bare granite, covered with a film of what looks like scarlet dust, which smells like violets, especially on being rubbed. It looks so perfectly harmless, that one can hardly believe it possible it should affect the solid granite in any way. Yet it does; to a very small extent, indeed, but just sufficiently to prepare the way for two large brown lichens, which are the next to make their appearance; and then the work proceeds more rapidly, in the way already described, until at last tall pine-trees rear their heads and find sufficient food and foothold, where but a few years before there was nothing but a bare surface.

The pines are much more imposing in appearance, and look capable of much greater exertion (as they are in some

ways), but they could not have done what the lichen does; and but for the lichen, they could never have grown here at all.

Lichens, as we have said, are able to eat into the rock, as oxygen eats into iron, and by similar means, for both are strongly acid; and on removing lichens from a stone one sees indentations similar to those left on a piece of iron by the removal of rust. But what is true of lichens is true in a degree of all plants. The roots of all plants, that is to say, are acid, though in a less degree, especially the young, fine, hair-like roots; and if these find their way through the thin soil to the rock beneath, they eat into it, leaving a distinct impression of themselves upon it when they are removed. The finest hair will leave its mark.

But roots also exert a powerful influence upon the rocks in another way. A very common method of breaking up the rocks in use with quarrymen is to drive into them plugs of very dry wood. These plugs are then watered, whereupon they swell with such force as to split even the hardest granite. Roots act in a similar manner, though less violently; and by swelling in every direction, they gradually widen any cracks into which they have found their way, and actually wedge off large slices from the sides of hills and cliffs.

In the neighborhood of Mount Etna people make the roots of the prickly-pear work for them in this way, for they want to hasten the breaking up of the lava, in order that they may turn it to account as soon as possible. The lava cracks as it cools, and in every crevice that appears they insert a branch of this cactus, which not only lives, but soon begins to grow, thanks to the warmth, sunshine, and moisture of the genial climate. Its roots cannot, of

course, penetrate the lava, but they can and do make their way into every crack and cranny within reach, and as they grow and swell they break up the rock into fragments.

As to what the plant lives upon in the absence of soil, it must be remembered that often a very little mineral food is enough for a plant, if only it is able to make the most of what there is and has plenty of water; then we must remember, too, that lava is especially rich in the materials required by plants, and that water flowing over it, or draining through it, would certainly dissolve some of these materials and bring them within reach of the roots, which would obtain them in this way quite as well as from soil.

But we have now to consider other means by which nature prepares the soil. Hitherto we have confined our attention to what is done with the rocks on the spot, the soil being left where it is made; but this proceeding is attended by certain disadvantages: the soil rarely attains any great depth, for one thing, as the rock below is protected more or less from frost; and then, again, generally speaking, one kind of rock alone does not contain all that is necessary to make a really fertile soil rich in all the various mineral matter required for luxuriant crops. If we look at those soils which are acknowledged to be the richest in the world we shall find that, as a rule, they have been much mixed. We say as a rule, because most of the lavas are rich enough in the minerals which plants require, and are also so well drained, thanks to the cracks and fissures within, that they do form most productive soil when simply crumbled down.

With the granites, however, the case is very different:

they are poor in the necessary minerals to begin with, and what they do possess is, as we have seen, dissolved, and in great part washed away. Granite slopes are poor and sandy, therefore, while the clay deposited at their feet is too stiff and compact to be fertile; and nature seems to tell the farmer as plainly as she can that in most cases he will not find it worth his while to try and grow wheat either on the hills or in the dales of a granite district. Of course, where granite decays on the level, and its various minerals remain, all crumbled down and mixed together, it is naturally more fertile than where the best of them are washed away; and thus we find that the granite soils of the Scilly Isle are far more productive than those of the Scotch hills, and are capable of bearing good crops of corn, in part at least, because less of the potash has been washed away from them. But some thanks are also due to the more genial climate, for on the granite highlands of Dartmoor there is no vegetation but heath and coarse grass, and though one has heard of laborers attempting to cultivate portions, and not without some success, it is impossible to say that the soil is naturally adapted for either field or garden crops. The moor is flat enough, indeed, to prevent the separation of the sand and clay, and such minerals as the granite possesses are fairly enough mixed without much loss by washing; but the natural poverty of the rock is aggravated by its elevated situation on the one hand, and by the shallowness of the soil on the other, and the soil therefore labors under the two great disadvantages of a cold climate and want of drainage. To the latter of these are due the many bogs which abound, not only on Dartmoor, but on the granites of Scotland, and the serpentine rocks of the Lizard as well.

The soil of the chalk downs is like that of the granite table-lands in one respect, that it is derived chiefly from the rock beneath, and has had little advantage of intermixture with others; but—and this makes a vast difference—the underlying chalk absorbs water readily, like a sponge, so that bogs have no chance of forming. The downs grow excellent pasture, and are especially adapted for sheep-farming; but if people will plow up the soft fine herbage of nature's providing and try to grow corn and turnips instead, they must not be surprised if they get poor crops in return for much labor.

Most of the richest soils of the world have been mixed, either by the work of rivers, or by that of other laborers to be considered by and by. And besides being mixed, they have in many cases been transported from situations where they were comparatively useless, to others where their good qualities can be turned to the best account.

The richest soil in the world is of little use on a lofty mountaintop, for none but lowly plants can stand the cold and exposure, and anything to be called luxuriant vegetation is impossible.

But in numberless instances soil has been brought down from the mountains, where it must have been comparatively unproductive; it has been mixed and prepared, and finally spread out in extensive fields ready made to the farmer's hand, in situations where his crops can have the warmth and moisture which are essential to them.

It certainly does appear perverse, therefore, that men should persist in trying to grow crops where they seem plainly meant to feed their sheep; and that they should want to plow up moors and deer-forests which could never make productive fields, when by long and most elaborate

preparation thousands and millions of acres have been provided which would yield abundant harvests with less than half the labor.

QUESTIONS FOR REVIEW

1. Describe the earliest forms of vegetation which are found upon rocks.
2. How do these lichens receive nourishment?
3. Show the steps by which soil accumulates upon the rock.
4. By what different means do roots break up the rocks?
5. Why is the soil of a granite district apt to be poor?
6. Explain the difference between the granite soil of the Scilly Islands and of Dartmoor.
7. What is the character of the soil of the chalk downs, and why?
8. What process is necessary before a soil can be very fertile?

CHAPTER IV

SOIL-CARRIERS

We have now seen by what means the rocks are crumbled down; but in many cases much besides crumbling is necessary to convert rock into good soil. Nearly all the soils which we look upon as especially fertile have been made so by being mixed.

When we consider which are the best corn-producing regions of the earth, our thoughts naturally turn first to Egypt, once the granary of the world.

And what is Egypt? "The gift of the Nile," as the ancient historian says. The soil which produces such wonderful crops has not been produced by the decay of the rocks upon which it rests, but is a mixture of soils brought in great part from the lofty mountains of Abyssinia, hundreds of miles away. The only fertile tracts in Abyssinia itself are due to the sediment washed down from these mountains, which are rich in the minerals most desired by plants, but like the Cheviot Hills already mentioned, unproductive, owing to their height and the consequently severe climate.

The top of this magnificent chain of mountains is a vast table-land, upon which the rains descend heavily and incessantly during some three or four months of the year, the fall being so abundant as to supply five tremendous mountain-torrents, which rush down the sides of the mountains with the force of cataracts, and carry with

them enormous quantities of rock, which is ground up bv degrees into the finest mud and poured into the Nile. So large is the amount of sediment brought down by the river—which those who like statistics may be interested to know is about equal in bulk to a solid cube measuring more than five feet each way transported in every second—that the river-bed is gradually rising, and the inundation therefore extends further and further; and very, very slowly, but still surely, more of the desert is being converted into fruitful soil. Left upon the Abyssinian Mountains, the materials of which this sediment is composed would have had little or no value—for man's purposes, at least—but transported to the magnificent climate of Egypt, and mixed with other matter, they form a soil which is the very perfection of fertility.

The sediment is not all deposited on the land or in the river-bed, however; much is carried into the Mediterranean, where another delta is being gradually formed, equal no doubt to the old one in richness, and capable of bearing crops as abundant, should it ever rise above the waters. A delta is possible only where there is little or no tide, or current, to carry the sediment away.

But it must not be forgotten that something more has been done than merely to transport this wonderful soil. It has also undergone much mixing, and consists not only of mud washed from the Abyssinian Mountains, but of sand, which is blown into the river in vast clouds from the desert. The Nile itself, too, has done a great deal of grinding, and sand and mud making, as well as its tributaries. Sand, driven by water, will wear away the hardest rock by degrees; and by means of the sand which the wind blows into it, the river has cut its way through the

rocks, scooping out for itself a wide, deep bed. The solid mass of rock thus removed, grain by grain, has also contributed in no small degree towards the formation of the Great Delta.

But even this is not all. No soil can be really fertile, however rich in mineral matter, unless it contain some amount of animal or vegetable matter. And this, too, has been supplied to the Delta in an interesting and remarkable way.

Nile water, like that of all rivers more or less, contains a vast number of microscopic animals and vegetables, the lowest and simplest forms of life, which are not only left behind with the mud, but are killed in myriads where they come in contact with salt water. The Mediterranean being a tideless sea, this wholesale destruction cannot take place except at the mouth of the river, and for a certain distance beyond it in the sea. Fresh water being lighter than salt, flows over the latter at first, before the two mingle; and as sea water abounds in these minute forms of life to a much greater extent than river water does, and as fresh water is as deadly to the one as salt to the other, the destruction wherever the two come in contact must be wholesale.

But where rivers are affected by the tide, there the salt water flows up under the fresh, for many a mile above their mouths, carrying with it a living freight, which must, to a large extent, perish and be left behind; while the microscopic inhabitants of the river water are destroyed with equal certainty wherever they come in contact with that which is salt, or even brackish; that is, partially salt.

The whole of southern Louisiana, with its extensive cotton and rice fields, was made in like manner by the

Mississippi, which becomes a dense yellow torrent after it is joined by the Missouri, and brings down with it a heavy load of mud, ground from mountains three thousand miles away, which it has deposited in some places to a depth of three hundred feet.

And so again, on a smaller scale, the low plain at the head of the Lake of Geneva is formed of mud from the mountains, which the Rhône has brought down and deposited in the lake, adding to it year by year, until it has risen above the water, and Port Vallais, which stood on the margin of the lake in Roman times, now lies a mile and a half inland.

Inundations are caused usually either by excessive rain, such as that which falls periodically in Abyssinia, or by the melting of the snow in spring; but passing mention must here be made of certain inundations brought about by very different causes, namely, the work of the beaver.

This animal, though it still inhabits the north of Europe and Asia, is nowhere now so plentiful as in North America, where, also, the effect of its work in the past may best be observed.

But the beaver once abounded in England and Wales, and indeed throughout the greater part of Europe, as the names of many places, such as Beverley, Beverstone, Biverbike, and many others, plainly show. What we see of its work in America, therefore, is probably only a specimen of what it has done wherever it has been undisturbed. Here, at all events, thousands of acres of land have been submerged, at one time and another, as the result of its labors. As is well known, the beaver is in the habit of building dams; and these are often so solid and extensive as to stop up the streams and rivers in which they are

constructed, causing them to overflow and form shallow lakes.

But local floods were only the first result of its work; for the streams brought down with them the usual sediment, which was spread over the inundated surface, gradually raising its level, until the lake became a marsh covered with marsh-plants. Then, as the sediment still accumulated, the marsh-plants by degrees found the situation too dry for them, and died off; their places were then taken by grasses, and the lakes were thus converted into meadow-land, fertile, as river-formed soils usually are, and enriched by the decay of the marsh plants.

Rivers, then, must be reckoned among the most important makers and carriers of soil. But the wind, too, does much good service, though also occasional damage, from man's point of view, as nature's laborers are apt to do, in these disorganized days.

On the Lincolnshire Wolds, for instance, and on the coast of Norfolk, where the soils are light and sandy, the whole of the finer portion, as well as the seed sown, is sometimes altogether blown away by the equinoctial gales. One field near Cromer was sown three times in the course of a single spring, and was finally left to itself, all the upper portion of the soil being banked, like a snow-drift, against the hedge.

But for the hedges the wind would no doubt have spread the soil fairly over the neighboring fields. Its efforts on this occasion were, however, certainly misdirected.

As to the enormous distances which fine dust is often carried, we have positive proof in the brick-red or cinnamon-colored sirocco dust which falls thickly upon vessels

in the Atlantic at certain seasons of the year, and is carried to Europe as far inland as the Tyrol. This dust, which is exceedingly fine, has traveled thousands of miles on the wings of the wind, the greater part of it having been borne across the Atlantic from the banks of the Orinoco and Amazons. Its value as a fertilizer is recognized by the North American farmers, who use a similar deposit of "flint-earth" to mix with some of their heavy soils. Very fertilizing also must be the volcanic dust, which, being carried high up into the air, at times probably far above the cloud-region, is conveyed enormous distances before it finally sinks to the earth.

The most tremendous volcanic outburst on record is that of Krakatoa in 1883, when millions of tons of matter were hurled into the upper air, and dust, to the depth of two inches, fell a thousand miles off. The vegetation of the neighborhood was, of course, utterly destroyed, but in this instance it took less than five years to cover up the dismal scene of desolation with a fresh growth of tropical luxuriance. Just so Vesuvius is said to smother and destroy the crops in its neighborhood every eighth year; but it is this very fact which makes the soil so wondrously fertile during the other seven.

However, we are concerned just now chiefly with the work done by the wind, and must glance at one curiously interesting sample of it which has been observed in the valley of the Limagne, in Auvergne. Here there is no active volcano to furnish dust, and yet the fields seem to get it—and that, too, without the drawback of being suffocated every few years. Where does it come from?

The wind blows chiefly from the west and southwest, across the mountain-chain of the Dômes. The air on the

western side of the mountains is bright and clear, but that on the Limagne side is generally slightly hazy, and the haze seems to consist of fine dust. And when we inquire about the mountains, we find that they are extinct volcanoes, and are widely strewn with volcanic ashes, the relics of ancient eruptions, rich in the minerals which make the most fertile soils, and just in the condition in which plants can most readily make use of them.

QUESTIONS FOR REVIEW

1. Describe the various ways by which the soil of Egypt is made extraordinarily fertile.
2. What important part does the beaver play in the work of soil distribution?
3. Give examples of the work of the wind in scattering soil.
4. What curious condition of wind and soil exists in the valley of the Limagne?

CHAPTER V

SOIL-BINDERS

The materials being ground up, mixed, and in some cases transported, there are still important matters to be attended to before anything strictly to be called "soil" can be formed.

The first thing is to make the future soil settle down, since nothing of value can grow in a wandering sand-drift. The deposits, whatever they be, need protection against the washing of the rain and the drying of the wind, which will not only dry the surface, but blow it away in clouds if it is left exposed.

Even to this day the plains of Hungary suffer from dust-storms, though they have long been covered with vegetation; and we may easily imagine how much worse these must have been when sun and wind had full play, with nothing to check them.

It is clear, too, that where sand or volcanic ashes have been brought by the wind, the same wind may in many instances scatter them again. And where mud has been brought down by a river and deposited within reach of the tide, there it will be liable to be washed away, unless some means be taken to fix it to the spot.

Let us even look, for instance, at a railway embankment. It has been piled by human hands with a special object, and is a far more solid mass than if it had been merely blown together; but yet it to some extent wastes

away. Its bare, exposed surface is washed and wasted by the rain, dried and blown away by the wind; for there is nothing to protect it from either, to begin with. But this state of things does not last long. There is always plenty of seed floating in the air, ready to sow itself on any bare space it can find; so that in two or three years' time the embankment is overgrown with grass, whose roots are so matted together that further shifting of the soil is to a large extent prevented.

Of course, where seed is sown even before the soil is made, as we have seen in the case of lichens, there the mold as it is formed is kept in place and protected, and is able to deepen undisturbed. But where sand has been heaped together by the wind, or mud deposited on the coast, there something is needed to give it firmness, or else it will be dispersed again.

The sandhills on the plains of Venezuela, for example, are still constantly moving to and fro, here to-day and there to-morrow, except in one district, where they have been consolidated into a low range of permanent hills by a curious grass with tall, cutting, sword-edged blades, which grows so closely and with such rapidity that any paths made by travelers are quite covered up and destroyed by it in a few days.

The plants which are most useful for this work of binding the soil and giving it its first firmness are those which, besides growing quickly, also send out especially long roots, runners, or underground stems, often miscalled roots, which are pegged down at frequent intervals by real roots, much in the same way as the thatcher binds down the straw on the rick-top. The couch-grass and others have long underground stems of this sort, as the gardener

knows to his sorrow; and then there are the bindweeds, most appropriately so named, for they send out long, trailing runners above ground, having roots at each joint, which make them extremely difficult to get rid of when once they have established themselves in a garden. Their tropical relatives, the ipomæas—plants of much larger growth, but bearing similar convolvulus-blossoms of more brilliant color—are among the plants which render most useful service in the Bermudas by stopping the fine white coral-sand of the coast from invading and burying the neighboring gardens.

When the sand has been consolidated and improved by the growth and decay of these and similar plants, there follow shrubs and small trees, such as do not object to the saltness of the soil; and finally, when the way has been carefully prepared, the once barren sand-banks are covered with groves of coco-palms. It is a fact never to be lost sight of, that here, as so frequently elsewhere, the first all-important work is done by comparatively feeble instruments; the dust-like lichen prepares the way for the pine, and the insignificant salt-worts, and weak-stemmed, creeping bindweeds make ready for the palm.

The mangrove, like the coco-palm, thrives in salt water, but is unlike it in being able to grow without any preparation, and itself does much to consolidate the mud in which it grows. It is found on many tropical coasts, growing between high and low water mark, and in river estuaries washed by the sea during one part of the day, and left exposed during another. From its branches it sends down long roots which, on reaching the mud, fix themselves firmly in it, and become independent trees; and the seed, which begins to germinate and grow while

still in the fruit and on the bough, also sends out branches and roots, sometimes long enough to touch the ground, before it falls. The fruit-roots, branch-roots, and stems, together form a tough, closely woven network, in which the mud of the river is caught and entangled, and converted into solid, or something like solid, land, very much more quickly than it would be without their help.

In Holland the people have taken a leaf out of nature's book, and carefully plant the sea-dikes, on which the very existence of their land depends, with the "sharp rush," whose multitude of roots mat together near the surface, besides striking deep into the soil.

The growth of the sea-reed is even more remarkable. It will grow in the very driest soil, and has been planted in the Hebrides to cure sand-drift. Its runners are often as much as twenty feet long, and so tough and strong that they have been used for rope-making.

Some quite fragile-looking roots are indeed remarkably tough, and capable of resisting an immense strain without breaking. The roots of the Lucerne clover are said to be often as strong as those of an ash-tree, though, of course, very much finer, and looking much weaker; and they have at times given unmistakable proof of their strength, not merely by resisting the advance of the plowshare, but by actually breaking it.

On mountain slopes, too, the roots of trees and brushwood serve to keep in its place the soil which must else slip down by its own weight, even if there were no rain to wash or wind to blow it. And where people have been so short-sighted as to cut down mountain forests, there they have had to lament not merely the ruin, but the

actual loss, of the fields in their vicinity, which have been carried bodily away.

In some parts of the French Alps half the cultivated ground has been washed away, owing to the reckless destruction of the pines; and this is not all, for when the forests are gone, not only does the soil follow, but so do the avalanches; or rather they come! plunging down from the heights above and overwhelming everything in their way. The trees, and the trees only, were strong enough to resist them.

It is remarkable what a very slight obstacle is often enough to stop the onward motion of a sand-drift, a few oleanders, by no means very sturdy shrubs, being often found sufficient for the purpose in the Bermudas.

In the wide plains of South Hungary, where the wind has nothing to break its force, the railway lines are often in winter blocked with snowdrifts, which there seemed to be no means of preventing, until in one part the experiment was tried of planting hedges of Pronins roses on each side. The hedges are of the height of a tall man, and the lines were kept clear during some exceptionally heavy falls of snow a few years ago where they were invariably blocked before.

On the southwest coast of France there is an extensive sandy region known as the Landes, which at one time seemed likely to be converted into a veritable Sahara, and was saved from this fate by nothing else but the planting of pines.

In the last century the sand-dunes were always in motion, constantly changing their places, ebbing and flowing like the tide, but creeping gradually further and further inland. When the storm-wind blew from the west it

caught up the sand and scattered it over the adjacent country, where it fell like volcanic ashes, doing equal damage and none of the good, for it consists to a large extent of fine white quartz, the most hopelessly barren sand there is.

In ancient times this district is said to have been fairly well covered with oak woods, remains of which are yet to be seen; why and when they were destroyed seems to be unknown, but the results were disastrous, and even alarming. At length, however, the happy thought came to an engineer named Brémontier, in 1787, that where trees had grown, trees might be induced to grow again, and the attempt was made, not with oaks, for they could not have borne the sand, but with the maritime pine. Over and over again it was tried and failed, owing to the shiftiness of the sand; but at length, by dint of immense perseverance, the seed was induced to take root, and then the worst of the battle was over.

One dune after another was brought to a standstill, and that which threatened to become a desert has gradually been converted into profitable pine-woods, with intermediate stretches of vigorous heather and furze ten feet high, and here and there a thick growth of hawthorn and holly.

We may conclude this chapter by mentioning the curious origin ascribed to certain patches of grass which occur frequently all over the bison region of North America. These patches are said to be evidently due to the bison's habit of wallowing in the dust, and were, in fact, the wallowing places of the herd. The repeated wallowing of a number of animals created shallow hollows or depressions which the rain converted into pools, where the water

lingered and into which it drained from the surrounding soil. Even when the water had drained away the hollows would continue damp for some time, and grass-seeds falling upon them would readily spring up. The grass-plants would speedily weave a network of roots over the whole, forming in time a thick mat by which the soil would be effectually held together and consolidated, and the bison who wanted a dust bath in future would have to choose a fresh wallowing place for himself and his companions.

QUESTIONS FOR REVIEW

1. Describe some of the plants which serve as soil-binders.
2. What peculiar qualities has the mangrove?
3. Give instances of the strength of these soil-binders.
4. What result has often followed the cutting down of mountain forests?
5. What expedients have been used for checking both snow and sand drifts?
6. Describe the growth of grass in the bison country.

CHAPTER VI

FIELD-LABORERS

The field-laborers whose work we are going first to look at are somewhat rough in their ways, it must be confessed, and not such as the farmer generally cares to see at work upon his land. For when he has taken possession of the beds of soft earth ready prepared for him, his plows and harrows come in very usefully, and he is of opinion that he can manage the tillage of his fields himself.

Nature, however, has no steel plows, and her fields must be tilled by other means, for they need it as well as the farmer's. And her laborers work in all parts of the farm, giving man a vast amount of help, for which he is often not as grateful as he might be, for he and they do not at present understand one another; and though he may tame a lion he cannot control a worm.

No soil is really fertile, whatever the mineral matter composing it, unless it also contain some amount of organic matter—matter derived from organized, living things, whether animal or vegetable. Organic matter alone is not enough to make a fertile soil; but with less than one-half per cent of organic matter, no soil can be cultivated to much purpose. Even with this quantity it will not grow corn of any kind successfully, but it will grow wild crops with less; and these in time add what is required, if they are let alone for many generations. The black earth of Russia, which is jet black when wet and

brown when dry, owes its color and much of its fertility to the finely divided and well-mixed vegetable matter which it contains, the remains of countless generations of wild plants, which held undisturbed possession there for ages, but have now made way for their betters.

All soils contain some amount of organic matter, animal or vegetable, but chiefly vegetable; and this is true even of such as seem to consist only of sand, clay, or chalk. For wherever it is possible for a plant to grow at all, thither something suited to the situation is sure to find its way. The wild crop may be a very poor one, perhaps only some coarse, wiry kind of grass—for there is hardly any soil so poor but that grass of some kind will grow in it—and when this has improved the soil a little, other better sorts may follow.

But it is the effect of animal life that we are now to look at. Animals, large and small, benefit the land by manuring it; but this is so obvious a benefit that we need not dwell upon it further than to remark that coprolites—the fossilized droppings and bones of animals of former ages—and guano, the droppings of birds, are among the most valuable manures which the farmer can use, and where they are not to be had upon the spot he finds it worth his while to bring them from a distance. When, therefore, we consider the abundant animal life which for ages occupied many of the lands now brought under the plow, we can understand one cause of their fertility—they have been regularly manured for ages. But besides manuring the land during their lives, the animals must have left their bones to enrich it also, whenever they escaped being devoured.

Burrowing animals have also been especially useful in

more ways than one. In the first place, they have added to the organic matter of the soil, and in the second, to the mineral matter also; and besides this they have done much to drain the soil, and expose it to the influences of the sun and air.

The organic matter which they have added, besides their own droppings, consists of the materials which they use to line their nests, principally leaves and grass, and also the remnants of their food, nuts, grain, acorns, and sometimes the whole of their winter stores.

They have added also to the mineral matter of the soil by helping on the decay of the underlying rocks. These are seldom at any great depth beneath, for the loose materials with which they are covered are but as a film of dust compared with the thickness of the solid mass. The soil at its very thickest is measured only by feet, while the solid crust of the earth is measured at least by hundreds of miles; and in most cases the soil is actually only a few, often a very few, feet thick.

In the western regions of North America, from Mexico to the Arctic Ocean, as well as in the northern parts of the Old World, there are a large number of small animals called by the general name of "ground-squirrels," and resembling tree-squirrels in many respects, though some of their habits are very different. Like the tree-squirrels, they lay up stores of food, but unlike them, they burrow in the ground, and live together in large villages instead of in pairs.

The gopher, or Canada pouched-rat, too, is to be found in the prairie, where it dwells not merely in thousands, but in hundreds of thousands, and has so completely taken, perhaps we should rather say kept, possession that

in some parts other quadrupeds are almost excluded. The gophers extend over hundreds of thousands of square miles, and have honey-combed millions of acres. One may indeed ride for days and even weeks through some districts, finding them everywhere as plentiful as if the whole district were one vast warren.

Other burrowers, better known in the Old World, are the marmots, which make very large and rather complicated burrows, and have quite riddled the rocks in Turkestan, in some parts of which they abound; and others again of the same great family of rodents, or "gnawers," the gerboas, have honey-combed the sides of mountains in South Africa, and possess such strong teeth that in the north they even gnaw through the thin layer of stone beneath the sand, and thus do some of the very first work of the pioneer laborers.

In England the field burrower with which we are most familiar, unpleasantly familiar, too, is the common mole. No matter where he lives, the mole's labors are not anywhere looked at with a friendly eye by farmer or gardener.

The sins alleged against him are: that he drains the soil so thoroughly by his network of underground galleries as to render it dry and barren; that he damages the crops by uprooting them, and by exposing, destroying, or eating their roots; and finally, that he uses such a large quantity of spring corn, as much as a couple of hundred blades, to make his bed, that where he abounds one-eighth of the crop is lost.

These are serious accusations; but the mole is not without friends, enthusiastic friends even, though probably not farmers or gardeners, and these declare that the damage done is slight compared with the service rendered.

The soil is greatly benefited, say they, by being upturned and lightened; and they claim that the mole takes high rank among nature's field-laborers, and should be honored accordingly, not only for his work as plowman, but also for his extraordinarily large and voracious appetite for smaller animals of all sorts, which do far more injury to the crops than himself.

Wherever a mole lives the organic matter in the soil must be continually receiving increase, for it lives almost entirely on animal food—such as worms, grubs, insects, as well as mice, dead birds, lizards, frogs—and as it is extraordinarily voracious, large numbers of these must be consumed, their remains, digested or not, being left in the earth. Large quantities of vegetable matter are also carried into its nest by the mole every year, and there they are, of course, left to decay. When, therefore, one thinks of the thousands of moles still existing, and the many more thousands and millions of past countless generations, every one of which lives, or lived, the same sort of life, always burrowing, always feeding, and always making nests year by year, it is evident that their effect upon the soil—in places where they are, or have been, plentiful—can certainly not be small.

And now we turn to another very different set of workers, most unlikely ones we should say at first sight, who are helping to improve and prepare some of the limy mud-flats of the East Indian Archipelago. At present, we believe, their work has been watched only on the Keeling or Coroz Islands; but what crabs are doing now crabs may have done, and have most probably done, in the past, so that some part at least of the present fertility of other mud-flats, perhaps of coral islands, may be owing to them.

But what, it may be asked, can crabs do? They burrow, for one thing; and they make their homes so close together, that as many as a hundred and twenty of these narrow, corkscrew holes have been counted in a space only two feet square, so that the ground is very thoroughly perforated indeed. And they not only burrow, but are incessantly busy carrying down twigs, bits of seaweed, scraps of coconut shell, seeds, and so forth, with the object of making themselves comfortable, it is to be supposed, and yet it almost seems as if they labored, some of them, in this industrious way simply and solely for the sake of improving the soil.

One of these crabs works so near the water that its burrows are covered at high tide; another works a little further in, and a third further still, where the mud is dry; but what is curious about this last is that as soon as the white, chalky mud has been turned into dark vegetable soil, which it is by the decay of the various things dragged into it, at once the crab goes off to another fresh spot, and begins all its work over again. Perhaps it does not like decayed vegetable matter; but the result is that it is always at work, and must get through a good deal of digging in the course of its life.

Beetles, again, are most useful workers, almost all the world over, and on some of the wild hill slopes of Ireland all the patches of good grass are said to be their work. Cows are kept on these wastes, and are attended by numbers of large beetles. Three or four of these together set to work at a patch of cow-dung, burrowing into the soil beneath, and bringing up little heaps of clay until they have covered it three or four inches deep. Their object, no doubt, is to make a suitable place in which to lay their

eggs, for the grubs when hatched live upon this food; but they at the same time provide a suitable bed for grass-seeds, which is quickly taken possession of.

The Dumble Dor beetle, or Flying Watchman, the slow, hump-backed, bluish black creature, which is often found lying on its back, goes to work in a different way, and in spite of its slow movements gets through what is really an amazing amount of work for its size. We all know it probably, though we may not all have watched its operations. It, too, is an attendant upon cattle, and works so expeditiously and in such large numbers as to clean a meadow tenanted by cows in three or four days. Instead of bringing up earth to cover the droppings, it removes them altogether, pellet by pellet. It digs its way down between the grass-roots, carrying with it as much as it can to a hole a foot deep, where it lays one egg; after which it crawls up again for more, over and over again, making many journeys. As many as forty or fifty burrows have been counted in one square foot.

Burying beetles, of one species or other, are everywhere plentiful, so plentiful indeed that we very seldom meet with the dead bodies of bird, mouse, or mole, or any other animal, in our walks in field or wood. All have been cleared away and buried several inches, sometimes nearly a foot, underground, where they benefit the soil, besides providing food for the beetle's family—this latter being of course the only object which the beetle has in view. They work sometimes singly, sometimes in company, scraping the earth away from beneath the carcass with their forelegs, and then carefully covering it up; after which they burrow down and lay their eggs. Four beetles which were kept and watched for fifty days, buried

in that time four frogs, three small birds, two fish, one mole, two grasshoppers, the entrails of a fish, and two pieces of ox-liver. But even rabbits are not too large for them; and one foreign species will bury a snake in a few hours.

QUESTIONS FOR REVIEW

1. What is necessary for soil beside mineral substances?
2. How has the soil been enriched in past ages?
3. What services do burrowing animals render?
4. Give instances of the diffusion of these animals.
5. What is the case for and against the mole?
6. Show how the crabs improve the soil.
7. Describe the field labors of various kinds of beetles.

CHAPTER VII

FIELD-LABORERS—CONTINUED

"The plow is one of the most ancient and most valuable of man's inventions; but long before he existed the land was, in fact, regularly plowed, and still continues to be thus plowed, by earthworms."

We have learned much about the earthworm of late years, thanks to Mr. Darwin; but long before Vegetable Mould and Earthworms was written—more than a hundred years ago, in fact—Gilbert White, the naturalist, of Selborne, had a very good idea of the worm's importance as one of nature's field-laborers. "A good monography of worms," he wrote, "would afford much entertainment and information at the same time, and would open a large and new field in natural history." "Vegetation would proceed but lamely without it, so great are its services in boring, perforating, and loosening the soil, and rendering it pervious to rains and the fibers of plants, by drawing straws and stalks of leaves and twigs into it, and most of all, by throwing up such infinite numbers of lumps of earth, which is a fine manure for grain and grass."

Gardeners and farmers hated the worm in his day, as the former at least do still; but he remarks that they would find "the earth without worms would soon become cold, hard-bound, and void of fermentation, and consequently sterile."

The earthworm is an animal possessed apparently of

more than the traditional nine lives, and endowed with a wonderful power of adapting itself to the most diverse and most adverse circumstances. Bodily injury affects it but little, so far as life is concerned. One worm is said to have been beheaded eight times in succession, and to have perseveringly grown a new head each time; another was cut into fourteen pieces, thirteen of which became perfect worms, while only one died.

Earthworms closely similar in appearance to those which we know in England are found in soils of the most various kinds and in almost all parts of the world. Moisture, however, they cannot do without, and hence, while they avoid dry sand and heaths, they frequent paved yards near houses in large numbers.

On the mountains of North Wales and on the Alps they are rare, owing perhaps to the lack of sufficient depth in which to make their winter burrows; but they are found in Scotland on hills fifteen hundred feet above the sea; near Turin, at a height of two thousand or three thousand feet; on the Nilgiri Mountains of South India, and on the Himalayas. They have, indeed, an enormous range, occurring in the most isolated islands, abounding in Iceland, and found in the West Indies, St. Helena, Madagascar, New Caledonia, Tahiti, Kerguelen's Land, and the Falkland Islands, though how they reached these is at present a mystery, since sea water is absolutely fatal to them.

Almost the whole surface of every moderately damp country is covered with a layer of fine, dark, vegetable mold; it is only a few inches thick at most, from four or five to perhaps twelve inches, but no matter what the nature of the soil beneath, there it is. One may see it in

any railway cutting, or on the top of any bank, be it chalk or be it sand; and this black earth, or humus, is, to a very large extent, the work of worms.

In a very loose soil worms can move easily, but generally speaking, as their bodies are soft, and cannot pierce through anything at all hard or close, and as they have nothing but their mouths to work with, they are obliged to eat their way through the ground. No doubt they are fed, to some extent, by the animal or vegetable matter contained in the soil, but their primary object in swallowing it does not seem to be food; to swallow it is the only way they have of getting rid of it, and their real object is to make a tube or burrow in which to live.

The effect produced upon the soil by its passage through their bodies is very marked: it is not only rendered extremely fine, but its color is gradually altered, becoming darker and darker, until, after repeated swallowing, it is turned almost black. The layer of dark mold which covers our fields is dark just because it is composed of the castings of worms—castings which have passed through their bodies over and over again, times innumerable.

The worm has no teeth, and its mouth is a mere opening, but it has the power of flattening its head and extending it on each side of this opening so as to form two lips, with which it is able to grasp leaves and other things firmly enough to drag them into its burrow. Sometimes, however, it seems to vary its manner of proceeding, and instead of grasping the object it wishes to move, it presses its mouth upon it until it adheres firmly by mere suction.

Worms are omnivorous: they will eat anything eatable, and will feed daintily upon half-decayed flowers and almost

any kind of vegetable matter, or coarsely upon their own dead comrades, or meat when put in their way. But their chief food consists of half-decayed leaves, enormous quantities of which are pulled into their burrows, torn into small shreds, and then swallowed and digested; and it is this vegetable matter which changes the color of the earth which the worms swallow with it, and converts it into "mold"—vegetable mold.

Two worms kept in a large pot of sand, well moistened, of course, but consisting only of mineral matter, converted the top layer into vegetable mold four inches deep, simply by the help of the leaves strewed on the surface.

Seeing only the little dark heaps of soil thrown up by worms on grass-plots and gravel-paths, heaps which are soon washed down again by rain, one has some difficulty in realizing the vast amount brought up in the course of a year. But Mr. Darwin reckoned that near Nice this amounts to from about fourteen to eighteen tons to the acre; this is supposing them to be as numerous and active over the whole of the field as they were in the one square yard chosen for observation; but it is also supposing them to work for only six months of the year, which he considered a low estimate. The largest amount was brought up on very poor pasture, where leaves were probably scarce, and the worms had to swallow much earth in order to obtain sufficient food.

On the whole it seems probable that they bring up more than ten tons of soil to the acre in many parts of England year by year, and that the entire mass of mold—the dark surface-soil of every field—passes through their bodies in the course of a few years, and is by these means sifted and rendered extremely fine, besides being thor-

oughly impregnated with vegetable and animal matter. Moreover, bones, twigs, leaves, shells, are constantly being covered with castings, and these further help to enrich the soil by their decay; whereas, left upon the surface, they would benefit it but little.

Besides grinding up the soil in the process of digestion to a state of extreme fineness, besides adding to it vegetable matter and darkening its color, worms are most useful in another way: they prepare channels through which the roots of plants are able to spread with ease. Plants evidently prefer, when they can, to take advantage of ready-made passages, and worm burrows which have been in existence some little time are usually found lined to the very end with fine roots and rootlets, the latter covered with fine hairs, through all of which the plant absorbs food. But that the worm's way of top-dressing lawns and paths does not improve the appearance of either, we must admit; top-dressing may be all very well in a meadow, or in the rice-fields of Bengal, which are very soon studded with worm-heaps after they have been flooded, but in a garden we are inclined to think it out of place. And it is true that, in the Botanic Gardens of Calcutta, the lawns are covered in a single night or two, if they are left unrolled, with tower-like castings, which weigh some ounce and a quarter each, and are anything but sightly.

Sometimes, too, the earthworm may disturb seedlings by burrowing, but it does not eat them. Neither does it touch living roots, as it has been suspected of doing, at least when these are growing in the open ground; though what it may do when confined in a pot, and pressed by hunger, is perhaps another matter.

The poor worm cannot work in dry soil. Indeed, moisture seems to be the one thing essential to it; for though it can stand much bodily ill-usage, it is actually killed by exposure to the dry air of a room for even a single night. In hot countries, such as Bengal, therefore, it can only work during the cool season, about two months, after the rains; and even in the moist climate of England it cannot work near the surface during the dry weather of summer, any more than in hard frost. Gilbert White remarked that worms worked most in spring; but he added that they were by no means torpid during the dead months, and were in fact out, even in winter, on every mild night.

There is, however, another and much smaller animal, which, as some people think, has done much work hitherto attributed to the overpraised worm. Ants have not generally had the reputation of being useful to the agriculturist, however clever some of them may be as agriculturists on their own account; but in Ireland, according to at least one observer, they do appear to have been most useful; and if in Ireland, then why not elsewhere?

However, whatever their respective merits, the ants work where and when the worms cannot do so, and are most useful where there are crags, or large stones, with patches of sandy peat; for the hill-building ants always choose rock to build upon, and gradually cover the surface with soil. These patches are at once taken possession of by grass and other seeds, and so the soil is kept in place. During the winter there may be a little loss by wind and rain, but the greater part is held together by the roots, and a patch of permanent vegetation is formed where previously there was only bare stone.

A single colony of ants seldom covers less than two square feet, and sometimes more than three; and as they generally choose a fresh place every year, they really do a great deal towards clothing bare places.

In the sub-tropical parts of South America and India, worms swarm out in endless numbers when the rain comes, but in the tropics proper, except in the moister regions, they are on the whole few. Not one was seen by Professor Drummond in Central Africa, even during rain, and he suggests that their place is taken in these parts by the termite, commonly, though erroneously, called the white ant.

The white ant lives underground, and being quite defenseless, it has such a dread of exposure that when obliged to come out for food it brings some of the earth with it, and builds a tunnel within which it always remains.

The food of the termite is dead wood, and not content with what it finds on the ground, it climbs the trees in search of it, toilsomely carrying earth for its tunnels wherever it goes. There may be perhaps a few feet of dead wood at the end of a long branch some thirty feet from the ground, and the whole distance must be covered in if the termite is to reach it. But as it does not know exactly where the food desired is to be found, it more often than not covers the whole tree with tunnels and galleries made on speculation.

The extent to which this tunneling is carried, and the amount of earth brought up, are something incredible. In some districts of tropical Africa there are millions of trees covered with tubes, every one of which must be plastered over with many pounds of soil. The tunnels

generally are about the size of a small gas-pipe, some occasionally larger, and here and there are large chambers covering nearly the whole trunk for some feet. Every branch, every twig has a tunnel, and as for the dead wood which falls to the ground, none is ever to be seen, as it is at once encased in soil. At first sight the traveler may think he has found a faggot, but on closer inspection it proves to be nothing but a cast in mud, a very perfect cast, with all, even the minutest knots reproduced. But of trunks, branches, boughs, or even twigs lying about on the ground, there is nothing to be seen. All are eaten up.

But the tunnels do not represent nearly all the termite's work, though they are much. Besides these, there are the nests, mounds of earth of huge size, which are a common feature of the African landscape, and can be seen for miles. In India they are seldom more than a couple of feet or so in height, but in Central Africa they are from ten to seventeen feet high and contain many tons of earth, while the excavations beneath are many feet and even yards deep.

The mounds are not solid, but composed of many tunnels, chambers, and galleries, yet they are so strong that they will bear the weight of a man on horseback. The exterior is, indeed, brick-like or stone-like in its hardness, but with all its strength it must give way at last beneath the fury of the tropical rains, which continue off and on for two or three months at a time, and thus the soil is returned to the earth enriched by its admixture with animal matter.

Ants, true ants, as well as white ants, abound everywhere within the tropics, but they also do a large amount

of work outside, though their numbers gradually diminish as we go further and further north and south.

There are "ant cities" in Pennsylvania, each of which contains more than sixteen hundred nests of various size, the largest being fifty-eight feet round the base and forty-two inches high, with galleries some sixty feet long leading to the feeding grounds.

The muscular power of these ants is truly wonderful. The loads they carry are twenty-five times their own weight, and they carry them what, for their size, is an enormous distance. It is as if a man of ordinary size were to carry a weight of four thousand pounds from the bottom of a coalpit to the top of the Great Pyramid. And they have not merely to carry these loads, but first to prepare them.

The ant begins work by scratching with her forelegs like a dog; later on she bites, cuts, or twists off pellets of earth, during which process she often works like a collier on her back, and then she compresses the particles into a ball and carries them out. The only implements she has for her work are her mandibles, or first pair of jaws, which are placed outside her mouth, each jaw being furnished with seven teeth. These powerful jaws serve as pick, shovel, crowbar, saw, axe, and cart, all in one, and as the little creature grows old her teeth are gradually worn down by the hard work they have done, just as a workman's tools are worn.

Thus not only is fresh soil continually exposed to the action of air and rain, but ways are opened by which the same air and rain may penetrate to the underlying rocks and carry on the decaying process, as described in an earlier chapter. Nor must it be forgotten that wherever

there is decaying vegetable matter, there carbon dioxide and other gases are formed, which are absorbed by the rain in its passage through the earth, and increase in a very high degree its power of acting upon the rocks beneath.

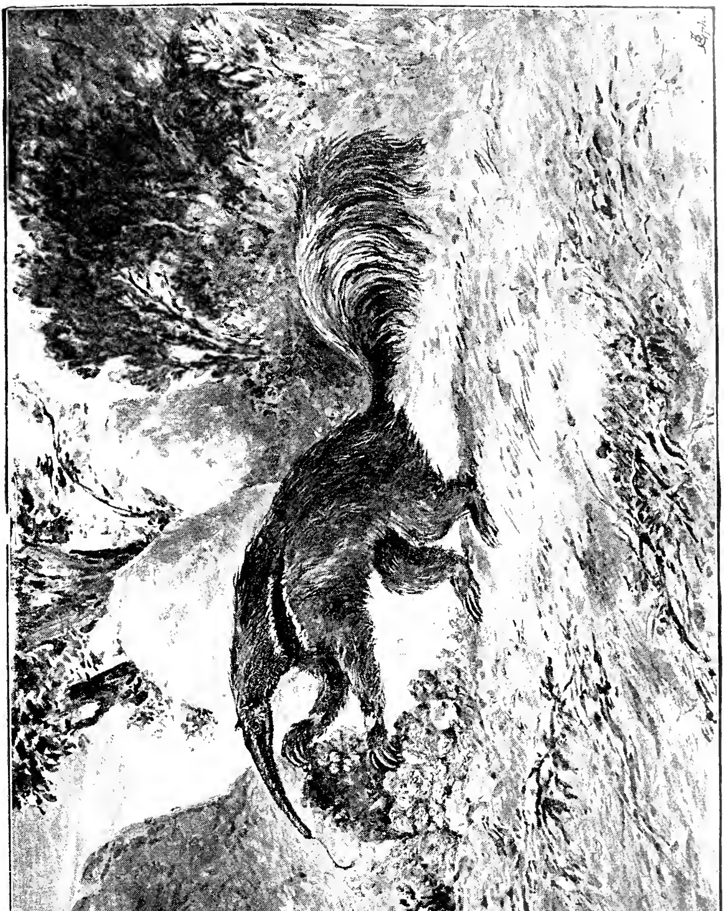
We cannot attempt to give more than a sketch, and that a very slight one, of the work done by nature's various field-laborers; but slight as it is, it would be incomplete without some mention of the very curious animals known as ant-eaters, which are found throughout the tropics.

These creatures have very long, thin, pliable tongues, looking like red earthworms, and as if they were endowed with independent life; and when they can get at them they lick up the ants with marvellous rapidity.

The ants, as we have seen, dwell, many of them, within walls almost as hard and strong as if built of stone or brick, capable, one would think, of defying the attack of almost any animal. But ant-eaters are armed with tremendously powerful claws—so powerful that with them they are able to dig and tear down even these strong citadels; and this done, they sweep up the terrified inhabitants by thousands.

The great ant-eater, or ant-bear of tropical South America, is like the Aard-Vark, but larger, and is so bold that it will sit up and fight even a "tiger," or more properly jaguar, with the very long, curved claws of its forefeet. Yet notwithstanding its size and strength, it lives chiefly on ants.

By this and other ant-eaters the hills and mounds of the ants are demolished, and the earth which they have excavated with so much labor is returned to the soil.



And it is returned in an altered state, much finer than before, and enriched, to some extent at least, by what has been added to it, and so is better fitted for the support of plant-life.

QUESTIONS FOR REVIEW

1. Describe the habits of the earthworm.
2. How is the soil enriched by them?
3. In what parts of the world are they found?
4. How do ants accomplish what worms cannot?
5. Describe the habits of the termite.
6. What remarkable "ant cities" are found in Pennsylvania?
7. How are these ants equipped for their work?
8. What does the soil gain from their efforts?
9. What part does the ant-eater play as one of nature's laborers?

CHAPTER VIII

WATER

The soil may have been ground and mixed, perhaps transported long distances, and otherwise prepared by the various laborers already described; but even then no crops, whether wild or cultivated, can thrive in it without moisture. In perfectly dry soil they must starve in the midst of plenty; for they can no more get at the food around them, however abundant it may be, without water, than if it were locked up. To them, indeed, under such circumstances, it is locked up.

Of course, we all know, as a matter of fact, that plants fade and wither, and eventually shrivel and die, if they be kept without water. We may know, too, that three-quarters of the weight of most plants, and a great deal more of many, is made up of nothing but water. But when once they have had a supply of water, why should they need more? Cannot they keep it? and if not, how do they lose it? Why do they need constant watering?

A potato is watery: only one-fourth of its weight is solid matter; the rest is all water. An artichoke contains still more water, and still less solid matter; a turnip is more watery still; and a pumpkin contains only five and a half per cent of solid matter.

And yet, when we have stored our potatoes and turnips, or our pumpkins, we do not find it necessary to

water them. They do not shrivel; they keep their moisture. Why does not a plant do the same?

The only answer to this question is, simply because it can't. It cannot shut the many mouths by which it is constantly losing moisture. We human beings cannot prevent the escape of water through the pores of our skin, or in the breath which we breathe; and the plant is in similar case. It is constantly giving off water, and if the loss is not made up it must needs become dry and shrivel.

Almost every part of a plant which is exposed to the air, and not covered by a layer of cork or of thickened skin, is constantly losing moisture in ordinary air; and unless the roots can suck up enough to make the loss good, it droops, flags, withers, and dies.

The potato and the pumpkin are protected—the one by cork, the other by thick skin—and they are therefore able to retain their moisture for a considerable time. In a similar way, the stems of most woody plants and trees are protected by layers of cork, and often of fibrous bark as well, which almost, though not altogether, prevent the escape of water. It is the young, green stems, the growing parts, and the leaves by which it is chiefly allowed to go off into the air; and these are just the parts which especially need the mineral food, the food derived from the soil, which the roots are constantly preparing.

How are the roots to convey this food to the growing parts of the plant? Of course, they cannot do so; they can only make it ready, and then it must be pumped up to where it is wanted. Accordingly, as the water is drawn off, so to say, above, the sap from below—that is, water containing food from the soil—rises to supply its place.

A constant current, therefore, rises from the roots

upwards; but a great deal of this would be lost during its passage before it reached the young shoots but for the fact, already mentioned, that the trunks or stems through which it passes are protected against the air, and moisture can escape but very slowly through bark or cork, though it does still escape to some small extent.

When the sap reaches the green parts of the plant it passes off into the air as invisible vapor; or, rather, the water of the sap passes off in this way, and the food from the soil, the mineral matter, is left behind. But even from the green stems and leaves the water is not allowed to escape quite unchecked, else it might pass off too fast—faster than it could be supplied.

For anything moist, whether it be moist earth or wet clothes, dries when exposed to the air. The air sucks the moisture out of all, and the drier the air, the more quickly it sucks. Without some protection against this thirsty air, therefore, leaves and green stems would also be sucked dry, like anything else, and accordingly their outer skin is more or less thickened; and it often contains, or is covered by, a waxy deposit as well. We may perhaps have noticed how drops of dew lie upon the leaves without soaking in, so that when the dew is shaken off, the leaves are dry. This is especially noticeable on some shiny leaves, but also on some mealy-looking ones, as, for instance, cabbage leaves; and in both cases it is the waxy substance in or upon the skin of the leaf, which not only prevents water from soaking in, but also prevents all but a very small quantity of the moisture from being drawn out.

Then, if water is constantly passing off, and that in considerable quantities, how does it escape? A little, as we have said, passes off through the whole surface, but

the bulk finds its way out through special openings, pores, or mouths, to which the name of "stomata" has been given. These pores are extremely minute openings in the outer skin of leaf and stem, and vary very greatly in size and number in different plants. It is through them that used-up air and water in the form of vapor are allowed to escape.

The process by which vapor is given off through the leaf-pores is called "transpiration," and is not the same thing as evaporation, though like it, it proceeds more quickly in hot, dry weather. But evaporation goes on—or, in other words, the air sucks moisture—from the whole surface of a plant—from trunk, stem, and leaves more or less, and would suck much more than it does if it were not prevented.

Transpiration, on the other hand, is confined to the leaf-pores, and is the process by which the plant parts by its own action, so to say, with its superfluous moisture. In evaporation the plant is merely acted upon by the air; the moisture is sucked out as it is sucked from a wet sheet hung out to dry, or a piece of dead wood. In transpiration the moisture passes out through the proper openings, and the plant itself acts, or at least discharges one of the natural functions of its being. Evaporation may continue in a dead plant, but only a living plant transpires.

Both processes are affected by the weather, however, and both in a similar way.

Nothing, we know, dries on a very damp day, because the more moisture the air contains, the less it can take up; or, in other words, evaporation proceeds slowly in moist air. So, too, transpiration almost or quite ceases

in damp weather, or when the leaves are wet. But both go on more briskly in the sun, in dry air, and more especially in a drying wind.

The leaf-pores by which transpiration proceeds are usually more abundant on the under surface—the shady side—of the leaves, and are few or altogether wanting on the upper surface, where they would be exposed to the sun, and water might pass off too rapidly. In moist, shady situations there is no danger of too much transpiration, and plants growing in these not only have more leaf-pores than others, but can also have them without risk, both on the under and upper surface of the leaves, for here transpiration goes on more slowly, and the loss of water is also easily made up.

Thick, fleshy leaves have the fewest leaf-pores, and thick, fleshy leaves are particularly characteristic of hot countries, where plants can afford to lose but little of the scanty supply of water which comes to them.

Many leaves which are alike on both sides have about an equal number of pores above and below; but when there is any difference, as, for instance, where one side is dull and the other glossy, the dull side, which is also the under side, has the larger number of pores. The leaves of the laurustinus have no leaf-pores at all on their shiny, upper surface, neither have those of the lilac; while those of the carnation, which show no such difference as these do, have about an equal number on each side. Some leaves have as many as one hundred and seventy thousand pores to the square inch, but this seems to be the largest number. An apple-leaf of ordinary size has about one hundred thousand leaf-pores altogether.

The size of the pores varies very much, but at their

largest they are so minute as entirely to exclude the very finest dust. Those of the white lily, for instance, which are called "remarkably large," measure only one four thousand two hundred and fiftieth part of an inch across.

Hard, evergreen leaves, such as those of the pine, are like the thick, fleshy ones in this, that they have but few leaf-pores, and lose but little water except through these openings. For pines grow in very dry, sandy soils, and often in elevated situations, where the air, though cold, is exceedingly dry and drying, and they therefore need as much protection as plants which grow in hot, dry climates.

Many and various are the devices by which evaporation is checked and controlled, even in temperate latitudes, lest the plant's need of water should exceed the supply. For it must be remembered that air has an immense appetite for water; the drier it is the more it takes up, but it goes on sucking, if allowed, as long as it is in contact with anything containing moisture until it can hold no more.

It is this which makes the misery of an east wind, which is a very dry wind, as well as a cold one, and sucks up moisture wherever it can, not only from vegetation, but from the bodies of animals, drying the skins of human beings as the hot, dry air of the desert dries them, though in less degree.

Since three-fourths of the weight of most plants, and more of many, is made up of water, the air would be always sucking at them, if not prevented. As things are, however, though some, generally very small, amount of water is sucked by the air from the whole surface of a plant, as we have said, its escape is confined, as far as

may be, in most cases, and especially in dry climates, to the legitimate openings, the pores made for this purpose.

Soft, thin leaves lose water by evaporation from the whole surface, and have a large number of pores as well, but they grow in situations where they can easily make up the loss. All leaves, however, have some protection more or less in the skin which covers them, this skin being, moreover, as we have said, impregnated with wax, which, though commonly invisible, often appears as a shiny coating, or as "bloom."

A cabbage, for instance, has a mealy look about it, as if it had been dusted with flour; many grasses, acacias, and now well-known Australian gum-tree or eucalyptus, have a similar appearance, and when this "bloom" is examined it is found to consist of minute rods, or needles, of wax. The substance forms a regular incrustation on the stem of the Peruvian wax-palm, whose native land is one of the most rainless regions of the earth; and there is nothing more effectual than wax for excluding air and preventing evaporation. Honey stored in wax-cells is, as it were, hermetically sealed up and preserved.

With the wax is often associated resin, which acts in a similarly protecting way apparently. No explanation indeed has hitherto been given of the use to the plant of gums, resins, caoutchouc, and the strong-smelling oils frequently found in leaves; but as water in which gum or any other substance is dissolved evaporates more slowly than pure water, it seems not unlikely that one at least of the uses of these substances is to check the escape of water. And this seems the more probable when we consider that aromatic as well as gum and resin-bearing plants are especially characteristic of deserts and dry

regions, hot or cold. Thus the pine-tree of the north has its turpentine, the eucalyptus of hot, dry Australia its oil, and the acacias of Africa their gums.

Many trees and shrubs in hot, dry countries are protected also by having either small or very few leaves, or even none at all.

Where the air is constantly damp, as it is in many parts of the tropics, there the trees may boldly venture, as the plantain does, to spread broad leaves many feet square to the sun, for the water-supply never fails, and the air is not outrageously thirsty, as it is in the desert. But in those parts of Australia where rain is scanty and droughts are frequent, there the leaves are not only small, as we have said, but they, most of them, also protect themselves by turning only their edges, not their broad sides, to the sun; for they have to economize their resources as much as possible. This is particularly the case with many species of eucalyptus, some of which turn one leaf-edge to the earth and the other to the sky, or stand erect, turning one edge towards the stem and the other away from it, in each case exposing themselves as little as possible. Their leaves, too, are for the most part narrow, and so scantily distributed over the branches that an Australian forest has none of the deep shade which the word naturally suggests to us.

But when the eucalyptus is transported to other lands, where it has plenty of deep, rich soil, and moisture in abundance, then it puts on more foliage, showing that it was only the dry heat of its native climate which made it so sparing of its leaves.

Most of the many species of acacia found in Australia go even a step beyond the eucalyptus in the way of econo-

mizing their foliage, and give up having any true leaves at all as soon as they are full-grown. They keep their leaf-stalks indeed, but there are no leaves at the end of them, and instead there are "wings," or narrow, leaf-like margins, growing out from each side of the stalks. Even these "wings" do not venture to face the sun, but turn their edges to earth and sky.

Acacias are especially the trees of deserts; they are, indeed, the only timber-trees of the Arabian Desert, and they abound in Africa, as also in Australia. But wherever they grow they are characterized by the lightness of their foliage; and of the Australian species, which number something under three hundred, two hundred and seventy drop their leaves altogether when they are grown up, and merely flatten out their leaf-stalks as described.

None of the cactus family—which are natives of the hot, dry regions of America, North, South, and Central—make any attempt at having leaves or even "wings," but their stems are flattened out and do duty instead. The stems, too, are protected against evaporation by being enveloped in a peculiar leathery skin, which is thickest in the species inhabiting the hottest and driest regions; and they lose little water therefore, except through the pores, which are but few in number. Thus protected, they not only exist, but flourish, in dry sand, where for three-quarters of the year they are exposed to the blazing, parching sun.

The tall, fluted columns of the species of cactus called the "torch thistle," sometimes fifty feet high, are to be seen springing out of crevices in the hard rock, and standing up like telegraph-posts on the mountains and in the rocky valleys all over the hot, parched, almost desert regions of New Mexico.

This tall cactus seems to be so fully protected by its thick skin that it may venture to expose its whole surface to the sun without risk; but other species are less bold, and keep close to the ground, growing in the form of large cushions, or great globular masses, and so diminishing the extent of exposed surface. Some, too, are set all over with long, slender, needle-like spines, and are also covered with what look like dense masses of floss silk, both of which protect the plant from the hot air and sun.

But though these special means of defense are more striking in the tropics than elsewhere, they are employed more or less everywhere, our own moist land not excepted. Besides the bark, and the cork, and the more or less thick skin of the leaves, and the wax, which we have already mentioned as the ordinary means by which evaporation is checked, these other measures are also frequently adopted for securing the same end. Our plants do not indeed go so far as to drop their leaves altogether, but some of them do greatly diminish both their number and size; and some clothe themselves with hairs, partly, as it would seem, lest they should be deprived of too much moisture, though partly also, probably, as a protection against insects. An example or two of these must suffice, and we will take, first, that of the amphibious persicaria—a particularly interesting plant, as it grows both on land and in water, and adapts itself to its situation in a very marked manner. When it grows in water, where, of course, it does not matter how much it may lose, it has smooth, lance-shaped leaves; but when it grows on land the leaves are narrower, and not only this, but they are covered as well with a quantity of long hairs, pressed close upon the surface, which they protect against evaporation.

Then there is the sweet woodruff, whose lance-shaped leaves grow in whorls of eight, for the plant dwells in moist, shady places, where there is no risk in having many leaves. But look from this to another member of the family, the quinsywort, and what do we find? The leaves are very narrow, and there are but half as many of them. Why? Because this little plant grows on dry banks, where many and large leaves would be dangerous to its welfare.

It has been already mentioned that the pine family, which thrive in dry, sandy soils, have hard, needle-like leaves, with few pores, and therefore give off but little water, either by evaporation or transpiration; and it is for this reason that the air in a pine forest in summer has none of the coolness which one finds in a forest of what the Germans call "leaf-trees." The needles of the pine they do not consider worthy the name of leaves.

Leaf-trees are continually cooling the air by the moisture which they give up to it; but the pine-needles have so few pores, and are so very much protected, that the little water they part with is not enough to produce any appreciable effect upon the air.

It is, perhaps, hardly necessary to do more than remind our readers that the evaporation of water is always accompanied by the absorption of heat; or, in other words, that water cannot be converted into gas or vapor, which it is when evaporated, without using up heat. Whether it be the heat of a fire or the heat of the sun, it is all the same. A certain amount of heat is required to make water pass from the liquid to the gaseous state, and if this heat be taken from the air, the air is necessarily by so much the cooler.

And this brings us to another part of the subject, the question, namely, as to the amount of water given off by trees and other plants, notwithstanding the various ways in which, as we have seen, they are protected.

We have distinguished hitherto between the two processes of evaporation and transpiration, because they are distinct; the one being due to the action of the air, and the other to the action, so to say, of the plant. Evaporation takes place whenever air comes in contact with anything moister than itself; whether it be animal or vegetable, whether it be wet earth or damp clothes, from all it draws water, and by its own heat converts this water into vapor. The other process, transpiration, is that by which, through the pores—the openings left in the skin of stem and leaf—the plant gives up, in a regular, systematic manner, the moisture with which it would else be overcharged.

But in both cases the water passes off into the air in the form of vapor; and in both cases it passes off as nearly pure water, all mineral matter being left behind; in both cases also, the amount given off varies with the weather, there being more loss on a hot, dry, sunny, or windy day, than on a damp, dull, still one. When, therefore, we consider the amount of water which passes off into the air from a plant in a certain time, it is generally impossible to distinguish between that which comes through the whole surface and that which comes through the pores; and both processes are frequently spoken of together as transpiration or evaporation. The quantity transpired is, however, usually very much larger than the quantity evaporated.

In some plants it is occasionally possible to see the

moisture coming from the leaf-pores, as it escapes faster than the air can evaporate it. This is the case with many grasses, especially the maize, which may be seen studded with actual drops of water.

A grass-plant gives up its own weight of water in the course of twenty-four hours, in hot, dry weather; and a square foot of turf will yield more than one and one-fifth pints of water in this time. But a square foot of long pasture-grass gives off nearly four and two-fifth pints, or as much as one hundred and six tons of water to the acre!

The larger the surface, the larger, of course, the amount of water which passes off from it; and therefore the extent of surface exposed is a matter of great importance, though it is also one which we are very likely to overlook, at least in many cases. Of course we can all see that a tropical plantain, with its broad, large leaves, has a considerable surface exposed to sun and air; and so with other conspicuously large-leaved plants. But when, instead of a few large leaves, a plant has many small ones, it is not so easy to realize what the whole surface may amount to.

A sunflower, for instance, has leaves of a good size, and yet it is rather surprising to find that in a plant only three feet and a half high, the whole leaf-surface may amount to more than thirty-two square feet! One specimen of this size was found to give up from a pint to a pint and a half of water during a day of twelve hours. The sunflower is quite outdone by the cabbage, however, one specimen of which gave off nearly two pints and a half in twenty-four hours, and that from leaves which, had they been spread out, would have covered only nineteen square feet. We have seen how well the cabbage is protected by

its wax coating against evaporation, so that almost the whole of this amount is given off by the plant's own action. The camellia is much less thirsty; it has fewer pores, and its thick, glossy leaves are so efficiently protected, that half an ounce of water, one-fortieth pint to the square foot of foliage, was all that one plant gave up in a day and night.

These calculations are comparatively simple; but when we come to trees, who would venture to guess at the extent of surface exposed to the air and sun by the leaves upon an elm? We look up at the quivering multitudes, and feel as if it were hopeless for any one even to attempt to count them; it is too bewildering!

Yet the calculation has been made, and the leaves on a not very large elm tree are said to be about seven million, which would give a surface of about two hundred thousand square feet, or five acres!

From the whole of these five acres of green surface, water passes off into the air in the form of vapor, to the amount of seven tons and three-quarters during each twelve hours of clear, dry weather.

But if this is the quantity returned to the air by a single tree of only moderate size, how large must be the amount received from a wood or forest, containing hundred or thousands of trees!

QUESTIONS FOR REVIEW

1. Give the proportion of water in the weight of different plants.
2. Why do vegetables live and plants die without water?
3. What is sap?

4. What prevents the moisture from leaving plants too rapidly?

5. What is the difference between evaporation and transpiration?

6. What conditions affect the number of leaf-pores?

7. Give some idea of the number and size of the pores in a leaf.

8. What is the nature of the coating or "bloom" of leaves?

9. Show how the acacia, eucalyptus and cactus adapt themselves to the climate.

10. How is this true of plants in temperate climates?

11. Why is a pine forest less cool than one of "leaf-trees"?

12. Give illustrations of the amount of water given up by plants.

13. What does this suggest as to the value of forests?

CHAPTER IX

DESERTS

From what has been already said, it is evident that every tree, every plant, every spire of grass indeed, is a pumping apparatus on a larger or smaller scale, by which a portion at least of the water which descends from the clouds begins to mount up again almost as soon as it has fallen.

Plants give up to the air, chiefly by transpiration through their leaf-pores, but partly also by evaporation from their whole surface, nearly as much water as is taken up by their roots—nearly, but not quite—for as long as they are growing they need some water for the formation of new shoots and leaves. The quantity is not much in itself, though water makes up a large part of the weight of most plants. But it is quite clear that, without water, they cannot grow at all.

Provided a plant has a plentiful supply of water, enough, that is, to make up for what it loses, it does not seem to matter how much it transpires. Some plants thrive perfectly well in dry air—where they give off moisture constantly and rapidly—if only their roots be kept in damp soil, and others thrive equally well in comparatively dry soil, provided the air be damp enough to check transpiration and allow them to retain most of the moisture they draw up. But when once a plant has thoroughly flagged, the case is different. Then nothing short of

water supplied to the roots will be sufficient to revive it. Damp air will be of no use; neither will the heaviest dew avail anything. The roots, and the roots only, can furnish the necessary supply.

Of course every substance—even, as we have seen, the hardest rocks—will absorb some amount of water when actually steeped in it; and so, if a withered shoot is kept soaking in water, it will absorb a certain quantity in time, as any piece of dead wood does. But leaves and stems have little or no power of absorbing moisture from the air.

This is the general rule, to which there are a few, but only a few, exceptions; lichens, which have no roots, do draw moisture from the air, and would be badly off if they could not, considering the bare rocks upon which they grow. Mosses, too, which grow where there is little or no soil, also supply themselves with moisture from the air to a great extent; and so it is believed do plants, such as the mistletoe, which grow upon others.

But still the general rule holds good; leaves have little or no power of absorbing moisture either from the air or from water poured upon them.

And yet, how the drooping leaves revive on a dewy evening, or in a shower of rain, or even under the influence of a shower from the watering-pot! The water cannot surely have had time to reach the roots, and then to travel up the stem.

Water certainly does travel upwards with amazing rapidity in some plants, as will be seen presently; but when leaves revive on a dewy evening, or during a shower, it is not because they have drunk in any of these fresh supplies. Moisture is constantly passing up to them in larger or smaller quantities from below; but they part

with it nearly as fast as they receive it generally, and faster than they receive it in dry weather. It is the want of sufficient moisture which makes them droop and renders them flabby. But when the dew falls on them transpiration ceases, or nearly so; they are able to keep nearly all the moisture sent up to them, and so they swell out again and stiffen, and hold themselves up.

A similar effect may be seen even in cut shoots which have been allowed to fade, and are then placed in very damp air. No moisture is taken up; quite the contrary; the continued decrease in their weight shows that moisture is passing off into the air, little by little, all the time; but stem and leaves are losing it very much more slowly than they did in ordinary air; and as water from the lower, older parts of the stem continues to rise, as it did before the shoot was severed from the tree, so the younger parts at the top, the leaves and buds, are refreshed and revived. Of course, this can go on only for a time; so long, that is, as any of the original moisture is left in the stem; and when this is exhausted the leaves droop as before, and at last wither entirely.

And now to gain some idea, if we can, of the rate at which water travels upwards from the roots to the leaves of a plant. This of course varies enormously in different plants, because some transpire so very much more than others; and it also varies greatly at different seasons of the year, according as the plant is growing, or putting out buds and leaves, or not.

Experiments made by watering plants with colored solutions are not very satisfactory, because the coloring matter may be caught and entangled, while the water moves on without them. Still, it is interesting to learn

that in the case of a white iris, which was watered with a blue solution, the white petals were streaked with color in from ten to fifteen hours.

A more trustworthy experiment made upon a willow seemed to show that the water in this case rose from the roots at a very much more rapid rate—thirty-four inches an hour. But the willow, having its roots always in or near water, has no need to be economical.

In a plant of maize, whose roots were in earth, the rate was much less, being little more than fourteen inches per hour; in a sunflower it was twenty-five inches; but in a tobacco-plant it was forty-seven and one-half inches per hour. The tobacco transpires so freely that its leaves droop as soon as gathered, and these experiments were made in such a way as to encourage transpiration to the utmost.

In some plants the sap rises with extraordinary rapidity; as, for instance, the water-liana. This is one of the many gigantic, rope-like creepers or "vines" of tropical America, and owes its name to the fact that clear, cool water fit for drinking can be obtained from its stem—by those, at least, who know how to proceed.

These climbers mount up among the trees far overhead, so that to cut off the top of one is quite impossible. A length of some seven feet has to be cut out where it is within reach, and this piece will yield about a pint of water; but it must be cut first at the top, otherwise, if cut first near the ground, almost the whole of the water will have rushed away into the vine high overhead before the second cut can be made.

This plant, therefore, seems to dispose of a pint of water in less than a minute, and almost all by transpira-

tion, since the quantity evaporated and the quantity required for growth in one minute must be exceedingly small. At this rate the liana pumps up from the ground sixty pints of water in an hour—seven hundred and twenty pints, or ninety gallons, in a day of twelve hours.

In early spring, when the sap is beginning to rise, the sugar-maple will sometimes yield as much as seven or eight gallons every day for three weeks, and this, of course, does not represent more than a small portion of the water which the tree has taken up, as it is only tapped, not drained of moisture. But the maple is far outdone by the black birch, another of the American trees from which sugar is made; for one specimen of this yielded, in four or five weeks, the extraordinary quantity of about eighteen hundred and ninety gallons. And this, like the sap yielded by the maple, is only a part, and a small part, of the moisture which the tree has drawn from the earth, and would in the natural course of things return to the air, diminished only by the small supply needed for fresh shoots and leaves.

But the amount of water which a plant takes up does not depend solely on the soil and climate in which it grows, but also on the plant itself. There is a wonderful difference in the power which plants possess of supplying themselves with food and water. Just as one man will live, and even thrive, where another would starve, so it is with vegetables. The lichen makes a living off the bare rock, where nothing else can grow; and the ice-plant carpets some of the most arid rocks of Greece, even after months of drought, and looks, too, just as deliciously cool as ever, its fleshy leaves being still covered with their characteristic "frosting," against which the hottest sun is

powerless. On closer examination the coating of "frost" turns out to be composed of innumerable globules of water contained in the surface-cells—the skin—of the leaf. A prick with a needle shows that these globules are just tiny bladders filled with water; but this skin is so exceedingly thin, and so perfectly transparent, that it is a mystery how the plants manage to keep their moisture; and it is often no less a mystery how they manage to obtain it in the first instance.

An English meadow, again, would wither and turn brown if it were left unwatered beneath the fierce heat of a tropical sun, but the grasses of the Kalahari Desert of South Africa remain surprisingly green, though they get but one or two falls of rain in the course of the whole year. Sometimes they get no rain at all for a twelvemonth; but even then, when they are the color of hay, they are equal to hay of ordinary quality as fodder for cattle, and hence are of course still very valuable. The wonder is how they manage to keep any life at all, and any nourishment in them, after so many months of burning drought.

In parts of Texas, where also rain is quite the exception, the grass is often destroyed during the hot months; but other green things contrive to exist, and these supply its place to the cattle. Timber is scarce in these parts; but within the last twenty years thickets of mesquite have sprung up, and now cover miles of prairie, where formerly there were none. And a most valuable tree the mesquite is, not only for fuel, fences, and for the framework of houses, but for food. Its light foliage takes the place of grass during the hot season, while its beans supply the cattle with abundant food in winter; and

it is enabled to bear the drought by the fact that it has huge roots, which weigh hundreds of pounds when the tree is only a few feet high.

But the prickly-pear cactus is almost equally useful, so far as the cattle are concerned, and it covers prairies so vast that the supply is simply inexhaustible. In spite of drought, and heat, and dry soil, the thick, stem-like leaves, or leaf-like stems, hold an enormous quantity of moisture, and when the thorns have been burned off even sheep can live and grow fat upon it. For horses and cows it is split open, and they eat out the inside, which is so succulent as to answer the purpose of drink as well as food. One can hardly imagine any other way in which water could be so successfully stored in these arid districts as within the thick, leathery skin of the cactus.

But the gourd family are almost as wonderful in the way in which they manage to appropriate and keep possession of water, even under the driest circumstances.

A pumpkin is all water, with the exception of five and a half per cent of its weight, and yet large pumpkins may be seen growing in what looks like nothing but sand. To be sure, their thick rinds enable them to keep the water when they get it, and sand is liberal in the way of parting with its moisture; but even so, knowing how very watery they are, it is strange to see them growing in such dry soil. Plants of this kind, however—gourds and melons—are especially characteristic of so-called "desert" regions, which are exposed to long-continued droughts.

Whenever there is more rain than usual vast tracts of desert land in South Africa are covered with melons, which provide food and drink both for man and beast. The sama, or wild water-melon of the Kalahari, grows in

great abundance in many parts of this desert; and the fruit, which remains good for a year in dry seasons, affords the natives almost their only supply of water when they are journeying across this rainless region. Evidently, therefore, the sama is able to make the most of its limited opportunities, and cannot only appropriate, but also keep, moisture, where most plants would simply perish of thirst.

Trying as are the droughts of the South African desert, they are less severe than those of Australia, for at all events such rain as does fall is kept, and sinks into the sub-soil, there being no rivers to drain it away; whereas in Australia the rivers quickly carry it off again. Even here, however, some trees, and among them the eucalypti, manage to store water in their roots; and from this supply the natives were in the habit of helping themselves in time of need. The long side roots were laid bare, as much as twenty or thirty feet, and divided into short lengths, from which water dripped at once, clear, cool, and free from any unpleasant taste or smell.

How the water remains so cool, buried only from six to twelve inches beneath the burning surface, is one of the many mysteries connected with the great mystery of life.

Water in a pipe, from which there was little or no evaporation, and water in a dead root, would speedily grow warm under similar circumstances. Water in a porous vessel keeps cool, indeed, in the hottest sun, because the vessel is porous, and water is constantly passing through it and being turned into vapor; with the result that the air immediately surrounding the vessel is being constantly cooled. The water is turned into vapor by means of the heat abstracted from the air.

But the water in the roots of the eucalyptus is not kept

cool by evaporation; else, in time of drought, it would be evaporated altogether. Besides, the juice of the hard, leathery-skinned pomegranate is cool on the hottest day; so, too, is that of the melon, with its thick rind; and the abundant juice of the thick-skinned mango feels as cold as iced water, even under the blazing sun of Ceylon; though the evaporation from any one of these must be very slight indeed.

Moreover, the coolness lasts only while the fruit remains on the plant, and disappears in a few minutes after it is gathered. It must, therefore, be quite independent of evaporation, and the temperature of a living plant's juices must be like the temperature of the blood in men and animals, quite independent of climate.

The ordinary temperature of the blood of human beings (98° F.) remains the same whether they live under the equator or in the Arctic regions.

And so it is with plants. They are cold-blooded, so to say, and cold-blooded they remain, even when surrounded by hot air, as long as they are alive. When they are dead their temperature soon rises or falls, according as the surrounding air is hot or cold. But if while alive, the temperature of their sap were affected by climate, or by the changes of summer and winter, day and night, then not only would it be constantly frozen in the Far North, and not far short of boiling in the tropics, but the sap of an acacia of the desert might freeze by night and almost boil by day—a sudden and violent change, which, as has been shown, wears out the very rocks.

But to return to the "deserts," by which we are to understand those regions where water is scarce, drought frequent, and where vegetation, though seldom or never

entirely absent, is more or less scanty, and more or less peculiar, because it is especially adapted to the special circumstances of its situation.

The soil of the desert may, or may not, be poor, but it is the want of water which renders these regions comparatively barren.

Well-watered, the Kalahari Desert might, it is said, be one of the richest grazing lands in the world; and the utter barrenness of certain tracts of the Sahara is owing merely to the lack of rain, for the soil beneath the sand is actually rich, and is not only quite capable of supporting vegetable life, but is extremely fertile wherever there is moisture.

The other marked characteristic of desert lands is the dearth, if not absence, of trees, and the question we have now to consider is whether these two characteristics—the want of water and the scarcity of all vegetation, but especially of trees—are brought about the one by the other.

Vegetation cannot thrive, though it may manage to exist, without a regular supply of water; but does vegetation bring rain or increase the rainfall?

There is no doubt whatever that where forests have been recklessly destroyed there the climate has been most seriously injured. The Ceylon coffee-planters cut down forests to make more room for their plantations, and many of them were ruined in consequence. The trees were gone, but so, to a large extent, was the rain also; and the additional space gained was valueless, for the coffee could not grow for lack of moisture.

So, also, the destruction of the olive-trees in Palestine has diminished the rainfall there, and with the rainfall the productiveness of the land, for centuries past. Now

DATE PALM ON THE EDGE OF THE DESERT.

that trees have been planted again the rain is said to be returning.

So much, then, is certain: cut down forests and you will have less rain; and though the natives of Namaqua Land, South Africa, attributed the great diminution in their rainfall to the presence of the missionaries, others had no hesitation in ascribing it to their own wasteful way of cutting wood.

But though loss of forest brings loss of rain, it is difficult to say precisely how the change is brought about, and whether rain is actually caused by transpiration or not.

Wherever there is vegetation, be it grass or be it forest, there, as has been shown, large quantities of water are constantly passing off into the air in the form of vapor. And the amount is large, not merely considering the means by which it is pumped up, but it is large actually; very large, when we compare it with the amount of rain which falls.

For instance, from the record kept at Greenwich it appears that during July, our wettest month, the average fall of rain is something under three hundred tons to the acre, or under three inches—three hundred tons during the whole month, or less than ten tons each day. But an acre of pasture-grass actually gives up more than ten times this quantity in the course of twenty-four hours—one hundred and six tons—that is to say, in a single day and a night. So that an acre of pasture which has received three hundred tons of rain in a month, gives up more than three thousand tons in the same time.

The question as to where this immense quantity comes from will have to be considered later. At present we are concerned only with the fact that so much water is returned

to the air. Whether it falls again on the same spot is another matter, and we have no proof that it does so. It may do so under certain circumstances, or it may be carried away by the wind and fall elsewhere, perhaps close by, or perhaps a long way off.

But if the air immediately over a certain district is being constantly cooled by the evaporation day after day of large quantities of water, does this produce no effect upon the air above?

What happens when water is boiled over a fire? Clouds of visible vapor rise from it, which we commonly call "steam." They are not properly steam, however, for steam is invisible. These are clouds, true clouds, consisting of minute globules of water, steam made visible, converted into water again by coming into contact with the air of the room, which is cooler than that within the kettle.

As heat converts water into gas or steam, so cold turns it back into water again. So when the earth is chilled at night the moisture of the air is also chilled on a large scale, and dew is formed—first on grass and leaves, because they are cooler than the soil.

If this be so, then when a current of warm, moist air comes in contact with the cool air over a forest, or over acres of pasture, will not some of its moisture be condensed into a cloud, as the steam from a kettle is condensed into a cloud when it escapes into the air, and may not this cloud discharge itself upon the grass or the trees?

Of course the cloud may be carried away; but it seems likely that, in some cases at all events, it will water the district above which it is formed.

There is a further question as to whether trees actually

attract the clouds or not, and this still waits for a satisfactory answer; but it is certainly the popular opinion that they do, and it is a very common thing to hear it said that the clouds have gone over to a neighboring park or wood, when the farmer would have been better pleased that they should water his fields.

As we began by saying, the subject is a difficult one; but though we may not be able to explain precisely the how, there is no doubt at all as to the fact that the presence or absence of all vegetation, not of trees only, does very greatly affect climate, and the climate in its turn affects vegetation.

For instance, Tacitus, the Latin historian, writing some eighteen hundred years ago, mentions that not even a cherry would ripen on the banks of the Rhine; and he certainly would not have believed that in centuries to come the same region would have become warm enough to be famous for its vineyards. But in his day forests abounded all about the river, and it is the removal, or great diminution, of these which has raised the temperature. A similar, but in this case disastrous, result has been produced on the southern slope of the Pyrenees, where what once were wide fertile tracts, covered with vegetation, have been turned into wastes by the destruction of the forests too recklessly carried out.

Wooded countries certainly seem on the whole to receive most rain; and the clearing away of any kind of vegetation, be it herbage, brushwood, or forest-trees, may be, and often has been, attended by evil consequences. For vegetation protects the soil from evaporation, enabling it at least to keep what water it receives; and as this accumulates, springs or reservoirs are formed, from

which the plants in their turn may derive supplies when rain fails or is insufficient.

Then again, vegetation preserves the soil from the assaults of wind and rain, a matter of no small importance, especially in mountain regions, for as we have already seen, the earth on the slopes may be clean washed or blown away, and the fertility of centuries may be thus destroyed.

But even this is not all. The soil gone, what remains?

Bare rock or subsoil, which is dried and heated by the sun, growing drier and therefore hotter, till it is quite parched. But a dry, hot surface heats and dries the air above it, for hot air, being lighter than cold, rises.

From a wide expanse of dry, hot sand, such as that of the Sahara, therefore, there must be a constant upward current of hot air, and this, again, must act like a furnace upon any moist current with which it comes in contact. The moisture has no chance of condensing into a cloud, or rain, as it might if it met with cool air, but is dispersed—drunk up and evaporated by the hot, thirsty air from below. No wonder, therefore, that the Sahara is a rainless region.

The Island of St. Helena, again, is a notable instance of what man can do in the way of reducing a luxuriant garden to a barren waste, simply by his ignorant or reckless destruction of its natural vegetation. When first discovered, the island, though very mountainous, and bounded by tremendous precipices rising some two or three thousand feet above the sea, was very fertile, and possessed a luxuriant growth of forest. For it is astonishing what a thin film of soil is enough for seeds to sprout in, if only it be moist; and it is astonishing, too, how little soil will

suffice even for hardy evergreens, birches, and other small trees, whose roots often grow in immediate contact with the rock. But one thing is absolutely necessary. If the soil be shallow, moisture must be abundant.

The soil of St. Helena was rich, being formed by the slow decay of volcanic rocks, but it was not deep, and was only kept in place by the roots which held it fast. The Portuguese brought goats to the island, and by these destructive animals the luxuriant vegetation was in great part destroyed, for they multiplied by thousands. There was a wanton waste of wood, too, on the part of the human inhabitants, though some were far-sighted enough to predict that the island would be ruined when the "great wood" was destroyed. And so, sure enough, it was.

Gradually the soil became more and more exposed, and whenever this was the case, it was washed away by the violent rains, leaving bare rock and utter barrenness behind. Still the destruction was allowed to go on, until, as the timber rapidly vanished, not only did the soil follow, but the rain deserted it also, and the governor, taking alarm, reported that the island, hitherto abundantly watered, was beginning to suffer from drought.

But the authorities—the island was then in the hands of the Hon. E. I. C.—were not to be persuaded that there was any connection between the loss of trees and the want of rain, and returned for answer that the goats were more valuable than the ebony-trees, and were not to be destroyed. So the goats stayed, and the ebony-trees went; and the general aspect of St. Helena became that of a dreary, rocky desert.

On the other hand, a change greatly for the better has

taken place in the region round about the Suez Canal. Here there was formerly hardly a blade of grass to be seen, and the land was a desert. But the cutting of the canal has brought water into the midst of the parched land; this soaks through the sandy soil, and everywhere herbage is springing up along the banks. Rain is still rare, but the air is moister; for the blazing sun draws up from the canal large volumes of water, which, though it is only invisible vapor by day, is chilled and condensed into water again by the lower temperature of the night, and falls upon the thirsty land as a heavy, refreshing dew.

But the very fact that it is a sandy district is in its favor in one way, for water soaks easily through it, and is thus brought to the roots of all plants growing within reach.

Then, again, in the Delta of Egypt there is much more cultivation than there was some years back. There are more corn-fields, more pastures, and even little forests are springing up, so that its general aspect is quite altered, and this change is accompanied by a change for the better in the climate also. Alexandria has rain, even to excess; and Cairo, which used to have at most five or six light showers a year, now has three or four times as much. The increase in the rainfall seems to be distinctly traceable to the increase in the amount of vegetation.

So impressed are the Americans of the West with the connection between want of trees and want of rain, that they now set apart a day in each year, which they call "Arbor Day," and dedicate to the planting of trees. Before this idea was started there had been such reckless cutting of wood in the mountains and timber regions as to cause quite a dearth even of fire-wood, especially in

what is called the "arid region" of the Western states. Now, however, more than six million trees are said to be growing on formerly barren lands, and Kansas alone has two hundred and fifty thousand acres of artificial forest growing up—a change which it is expected will so benefit the whole region that it will cease to be arid.

In this land we have little idea of the magic change produced in the appearance of the landscape by rain falling upon the hot, parched surface in southern latitudes. There, growth is so rapid that, in Ceylon for instance, a green hue begins to color the saturated ground after a single day's rain, almost between dawn and sunset, where all before was dreary brown.

But the change which takes place in the desert of Nubia is far more wonderful. During the dry season not a blade of even withered grass is to be seen; trees and bushes have shed their leaves—their very bark is cracked by the fierce heat. The Atbara—that mighty tributary of the Nile, to which its yearly inundations are due—has altogether ceased to flow, and is converted into a barren waste of glaring sand, four or five hundred yards wide, interspersed with a few pools here and there. And yet the tremendous torrents which pour down into it from the Abyssinian highlands have never ceased to flow; but the whole of their waters, to the last drop, have been evaporated on the way by the intense heat, or have been absorbed by the desert-sand which has accumulated in the bed of the river. Everything is parched, scorched, gasping; not only the sand, but the air is burning.

Such is the state of things towards the end of June. The Atbara is dead!

Then one night, when everything is suffocating, there

comes, suddenly, without warning of any kind, a sound as of distant thunder, a continuous roll and roar, which means that the river has arrived!

There, where there was only sand the day before, it flows five hundred yards wide, a mighty flood, and already fifteen to twenty feet deep; for the rain is pouring down upon the great table-land of Abyssinia, and it will continue to pour for two or three months to come.

And the change in all the bare and withered trees and shrubs, how rapid and how marvellous it is! In two days' time they show signs of bursting into leaf, having previously looked as dead as they do with us in winter; and as for the mimosas—their light, feathery foliage is already beginning to afford shade.

Yet there has not been a drop of rain, or even of dew. The air no doubt is moister, for evaporation from this wide expanse of water must go on at a tremendous rate. But at present it is too hot and dry to part with a single drop; and it is from the soil that the trees have received their fresh supplies, so quickly does the water soak through the sand. But this is not all that they will get. All nature seems to expect a change, for the wind is blowing from the south, and rain is surely coming!

The natives of South Africa say that the wind "smells of green grass" when the wind blows from a quarter where rain has fallen, though this may be hundreds of miles away; and thousands of cattle will start off sometimes and travel immense distances, in the endeavor to reach the fresh pastures of which the wind tells them. So keen is the scent of men and animals in lands which suffer from long drought.

QUESTIONS FOR REVIEW

1. Do leaves absorb moisture?

2. What makes them revive under rain or dew?

3. Illustrate the rate at which water travels from root to leaf.

4. Describe the peculiar qualities of the ice-plant, the grasses of the Kalahari Desert, the mesquite and the prickly-pear.

5. What other plants are utilized in desert regions?

6. What reasons show that evaporation is not the cause of the coolness of these fruits?

7. What does this teach as to the temperature of living plants?

8. What reasons point to vegetation as one cause of rain?

9. In what different ways does vegetation help to preserve the moisture of a region?

10. Illustrate this in the case of St. Helena and of Northern Egypt.

11. Describe the effect of the rising of the Atbara in Nubia.

CHAPTER X

ROOTS

Plants, as we have seen, need a constant supply of water for transpiration and for growth. They cannot, as a general rule, take this in by their leaves, and therefore must take it in by their roots; and without water the roots cannot take up and supply to stem, branches, leaves, flowers, and fruit that mineral matter without which the plant cannot exist.

Before examining the way in which the roots perform their work of supplying all parts of the plant with liquid food, we must briefly consider where the water comes from.

For if, as has been said, the ordinary rainfall in England for the whole month of July is about three hundred tons, and if an acre of pasture-grass transpires more than three thousand tons in the same time, it is quite evident that the demand far exceeds the supply from the clouds. Moreover, the grass does not get even the full benefit of that which does fall, for a very large proportion is either at once evaporated from the soil, or is drained away into ponds, lakes, streams, or rivers. Of the rain which falls in England between April 1st and October 1st, it has been calculated that ninety per cent is evaporated from the soil and returned to the air. From the air, however, the soil again absorbs it; for though leaves do not absorb moisture from the air, the soil does.

We speak commonly of the air as being "damp" or "dry," as the case may be; but in point of fact it is never absolutely dry, for nothing could live in it if it were. It always contains some amount of watery vapor, and whether it be large or small, soil which has been dried during the day regains some degree of moisture by night by the simple process of sucking it from the air. The air sucks it from the soil by day, especially during sunshine or dry wind, and the soil thus dried sucks it back again at night.

Some soils suck much more moisture from the air than others, and some are also able to keep it much longer than others. We all know that a sandy soil, for instance, is a dry soil: it takes some time to grow really damp, and it dries again very quickly. Indeed, pure quartz-sand seems as if it could not be moistened by anything short of rain or dew, being incapable of sucking any moisture from the very dampest air.

A chalk or limestone soil, on the other hand, acts like a sponge, and though it may dry on the surface, keeps its moisture a long time within. The subsoil of the Kalahari Desert, already mentioned, is limestone; and this is probably one reason why the grass there is able to remain green so long without rain. Such water as is received is kept for some time, stored up in the subsoil.

Of all kinds of soils, it is those containing most vegetable matter which take up most moisture, and also remain damp the longest.

It is a curious fact, however, that the soils which are least ready to part with their moisture to the air are also those which are least ready to part with it to the roots of plants. There may be actually more moisture in vege-

table mold than in sand; but the latter, at all events, makes the plants welcome to what there is, and lets them have almost every drop; while the mold may have more to give, but also keeps back more. If the two contained an equal amount of water, therefore, plants would actually be better off for moisture in the sand than in the mold; but this is not the case.

An experiment made for the purpose of trying different soils with regard to their readiness to give up their moisture to the roots of plants gave some very interesting results. The soils chosen were three: 1, loam; 2, a mixture of vegetable mold and sand; and 3, coarse sand alone; the loam held two and a half times as much moisture as the sand, and the sand and mold mixed held more than twice as much.

In these three soils were placed some tobacco-plants, which are very thirsty and very watery—four-fifths water, indeed. Their broad, tender leaves begin to droop as soon as gathered owing to their rapid transpiration. The sand gave up the whole of the water it contained with the exception of one and a half per cent, and it was not until it had reached this dry state that the tobacco planted in it flagged; the other plants flagged when the loam still contained eight per cent, and the vegetable mold and sand a fraction over twelve and a quarter per cent.

The supply contained in the sand was exhausted first, of course, because it contained so much less to start with; but though the other soils were not nearly as dry, the plants flagged because they could not get hold of the water which they still contained.

Some plants, such as rice, grow equally well in soil or water, but most plants are injured by having their roots

kept in water for any length of time, and are, as a rule, in better health when allowed to take up the moisture they need from that which is contained, invisibly, in the pores of the soil, when it does not look actually wet at all, and no moisture could be squeezed out of it.

But our main point now is to show that soil may, and does, become damp without rain. It may be dried by sun and wind by day, but it makes up for this by drawing moisture from the air by night, and it is this, partly, which enables plants at least to live through a time of drought, though their very stunted growth shows that the supply has been insufficient for their needs.

The moisture which the soil thus draws from the air does not remain on the surface, but like the rain and dew, sinks into the ground, penetrating deeper and deeper, and moistening the soil until it is used up, or stopped by meeting either with damp soil, or with soil or rock through which it cannot pass. Rain falling upon a porous soil, such as sand, or even soil containing much sand, passes quickly through it until it meets with a bed of stiff clay or rock, which prevents its going further; and then what is left, over and above what the soil has taken up, accumulates, and may in time form a spring, or even a sheet of water. In some places there are known to be very extensive underground lakes, and these must do much to keep the soil above them moist in the absence of rain. The springs, or underground streams, too, do the same, and in some cases they flow such long distances that it seems not unlikely the Kalahari Desert may have some such subterranean supply of water, which enables the plants to live through the long, terrible drought.

But it may be asked, What is the use to the plants of

water so far beneath as to be quite beyond the reach of their roots? The answer to which is that it does not remain beyond their reach, but is brought up to them.

The water in the soil, visible or invisible, is like a stream which is never at rest; it is in constant motion, always either rising or sinking according as the surface of the soil is damp or dry.

When the surface is wet from rain, the rain goes on sinking down and down till it is either absorbed by the soil through which it passes, or accumulates at some greater or less depth below. But when the sun shines out again, or a dry wind blows, the moisture of the surface is evaporated, the upper soil grows dry again, and the moment it is drier than the soil below, the damp soil begins to give up its moisture to this drier bed immediately above it. Thus the stream of moisture at once begins to ascend, and will continue to ascend until the surface is wetted again; it moves, in fact, either up or down, to the drier parts of the soil, whichever these may be, the movement being exactly like that of the oil in the wick of a lamp; as fast as the oil is consumed, more rises to take its place.

In time of drought the soil may appear quite dry even to some depth, but as we have seen in the case of the tobacco planted in sand, plants can continue to draw moisture from the soil long after all trace of moisture has vanished, so far as can be seen. To find it at all we should have to dry the soil by artificial heat; but it is there, and the plant manages to draw it out.

In very long droughts, even the springs near the surface may fail, all their water being drawn away from them by degrees; but still, at a greater or less depth, some water there is, for the deeper wells do not fail though

the shallow ones may; and unless this water be buried under some bed through which it cannot pass, it will continue to rise to the surface.

The water which plants need, therefore, for growth, and to supply the small loss by evaporation and the large loss by transpiration, comes to them from rain and dew; it is also very largely absorbed from the air by the soil; and the large stores accumulated in the ground are also drawn upwards as they are needed—chiefly, of course, during the spring and summer. In autumn, when growth ceases, transpiration is less; in winter, when the trees are bare, there is next to none, so that they have little need of water. In spring and summer, on the other hand, they need much, and receive it, in part, from the accumulated stores of the other months.

All the water which plants transpire—in many cases a very large quantity, as we have seen—is taken up by their roots, and their roots alone. And these roots we must now look at a little more closely.

A root is a very wonderful organ, much more wonderful than a passing glance would lead one to suppose. And, indeed, the most important parts cannot even be seen without careful examination.

The root serves two purposes: it keeps the plant in one place, enabling it to stand against the wind; and it collects from the soil food and water which the plant can obtain in no other way, and without which it can neither grow nor exist.

Some plants have a single fleshy root, like that of a carrot, which descends straight into the earth, and has no branches, but only a few fibers growing from it. A carrot needs a good pull to uproot it; but an onion is easily

lifted from the earth, as its roots are only fibers growing from the base of the bulb; while a dock may resist the full strength of a man.

Water-plants have few roots, as their food comes to them already prepared, without their having to search for it; bog-plants have more roots, as they have more work to do; and land-plants have most of all, as their roots frequently have to explore the earth for a considerable distance in search of food.

In a fertile soil, where there is plenty of food, roots are generally short and much branched. They branch out, in fact, where the food is to be found. But in a poor soil they have to go further to find what they need, and are usually long and slender.

But the mere mention of so many feet gives no idea at all of the real length of a plant's roots; for besides the long main roots, there are rootlets innumerable branching from them, and these rootlets, though they may be mere threads themselves, are covered with millions of hairs, generally so minute as to be hardly visible without the help of a microscope.

But here again, as we have seen in various ways before, it is the small, insignificant workers which are of the most importance. It is through the younger, threadlike rootlets, and through these millions of minute hairs, that food is chiefly taken up; and this is why, in moving a plant, the gardener is careful to keep a ball of earth round its roots, that the small, delicate rootlets may not be injured, and its food-supply lessened.

The root-hairs are being constantly produced in fresh millions, for each individual lasts but a few days.

It is difficult in any degree to realize what length of

root a plant possesses, for to do this one must measure not only the main root, or roots, but the branches, rootlets, and fibers as well; and even then, the fringe of hairs will have to be left altogether unreckoned.

An oat or barley plant, for instance, has roots several feet long; but when we say several feet, we merely mean that they stretch several feet downwards through the soil. Their real length, if the many roots are measured end to end, branches and all, is a very different matter. A barley-plant grown in a very small quantity of rich porous soil, was found to have a total length of root of one hundred and twenty-eight feet. This measurement included the fibers, but not the hairs. In loose soil, such as this, roots can make their way easily; but in closer soil, growth is more difficult, and so slower, and a plant grown in soil of the latter sort had roots only eighty feet long. Only eighty feet; but both the eighty feet and the one hundred and twenty-eight feet were packed into the fortieth part of a cubic foot of soil, a quantity which would be contained in a box between three and four inches square and equally deep.

Of course, if these roots had had their liberty they would have been much less branched, and would have spread much further. They would, so to say, have gone much further ahead, without running up so many bypaths. But being prisoners, they had to make the most of what they had, and so explored most thoroughly the small space at their command. Every one knows what a mat of roots and fibers there will be when a plant is taken out of a pot too small for it; such a mat that the earth is often completely enveloped.

Now, of course, it is not natural for a plant to grow in

a confined space, with its roots crowded together in this way, and when left to grow as it likes, in the open ground, its roots often roam to great distances, and therefore require much more soil than they make use of as food. The poorer the soil the farther the roots spread in their endeavor to find nourishment, and a maize-plant in sandy soil will send its roots out a distance of ten or fifteen feet.

It is supposed that only a very small portion, perhaps a hundredth part, of the soil helps to feed the plants growing in it. And this is probable enough when we consider it; for the soil, however fine, still consists of solid particles, which the roots cannot swallow; and though it is being constantly dissolved by water and gases, the process is a slow one. Where the soil is coarse the process is slower still. For as a lump of sugar takes much longer to dissolve than the same quantity of sugar when reduced to powder, just so it is with the soil; when it is fine the water has a very much larger surface to act upon, and can act more quickly. And this is one reason why finely ground soils are so generally fertile.

But this is not the only reason; for besides drinking in the moisture of the soil, with whatever may be dissolved in it, the roots do much dissolving on their own account. And it is for this purpose, apparently, that all, down to the smallest fiber, and even hair, are more or less acid.

What food comes to them ready dissolved may be brought from a distance from the soil above or below the roots, but it is brought. The particles of soil, on the other hand, do not move, and the roots must go to them, and actually touch them, and that very closely, for the acid to be able to act upon them. A rich morsel which

is a foot, or even an inch or a half-inch away, is of no use, except so far as it may be dissolved by water. The roots can do nothing with it unless some part of them, fibers or hairs, are near enough to get hold of it and press close to it, as the lichen adheres to the rock.

And it is this which makes it so important that a soil should be not only finely ground, but well mixed, so that all the ingredients may be within reach of the roots of each plant.

Most soils distinguished for their fertility contain a large proportion of fine matter, and to this is largely due the extraordinary productiveness of some of the lands of Ohio, which have borne heavy crops of wheat and maize for sixty years in succession. A considerable part of the soil here consists of particles which measure from the five-hundredth to the thousandth part of an inch across. The same thing is to be observed in the black earth of Russia, and again in the mud brought down by the Nile and other rivers: all are distinguished for the fineness of their particles and their thorough mixture.

Why is it that a block of granite is able to support only a few lichens and mosses? Chiefly because it is a block, into which roots cannot penetrate. It would not make a really fertile soil even if it were crushed into coarse gravel, but it would grow more than it does now; and if it were ground to fine powder and kept well watered, it would grow even corn—not perhaps good crops, though even granites differ in fertility, but still corn—whereas not a stalk can spring up while the granite remains a block, no matter how diligently it be watered.

By way of testing this point, an experiment was made with some barley sown in a soil consisting of pure feldspar.

Feldspar is that one of the three minerals of which granite is composed, which, when finely powdered and washed away, forms beds of clay. In this case it was first only coarsely powdered, and the barley grew to a height of fifteen inches; moreover, the ears formed, one ear ripened, and two seeds were perfected. In the second instance the feldspar was finely powdered, and the stalks were very much stronger. One grew to a height of twenty inches, and perfected four seeds.

Feldspar alone, though a compound of several elements, could not in any case produce a good crop; for the stiffest clay soils under cultivation have been not only well ground, whether by ice or water, but also mixed besides, and contain sand and other ingredients.

It is, of course, possible for the soil particles to be too fine, as they are in pure clay, which is so close in texture as to exclude what is as necessary to the plant as food and water, namely, air. A plant's roots need air as much as any other part of it, for they are constantly taking up oxygen, and hence all specially fertile soils contain a large proportion of sand, which makes them light and porous; for though fine, it is not nearly as fine as the particles composing the clay, and does not turn into a stiff paste when mixed with water.

In a stiff, heavy soil roots make their way with less ease and with less rapidity than in a light, loamy one containing a large proportion of sand, and therefore they must needs collect food less rapidly. Moreover, both air and water penetrate a heavy soil less easily than they do a light one, and hence not only is the air which the roots need less able to reach them, but less water can enter also, and consequently less soil is dissolved and made ready

for their use. The "loamy soil" which a farmer loves contains from forty to seventy per cent of sand.

Here, again, we see the great usefulness of earthworms. In sand they, like the roots, can make their way so easily that they have little need to remove the soil by swallowing it, the only means at their disposal. But in a stiffer soil they are obliged to do this, and thus they let in both air and water, to the great advantage of the plants, while they also spare the roots much labor by preparing for them airy passages, down which they can run with ease.

But though roots take advantage of these ready-made channels, and are evidently all the better for them, they do not let go their hold on the soil, but keep a close grasp of it, lining the worm-burrows with thread-like fibers, which cling fast to the sides.

Roots coming in contact with a piece of limestone will leave upon it a perfect impression of themselves, even to the hairs with which they are fringed, showing how, like the lichens, they have eaten their way into the solid substance.

How do they do it? We can hardly do more than conjecture; but it seems probable that the acid in the roots acts much as acid contained in a bladder would. If a glass tube is filled with water made slightly acid with vinegar, and then covered with a piece of moistened bladder strained tightly over the mouth, and in contact with the liquid, this will represent the root, though the resemblance would, of course, be closer if the tube itself were of bladder. This, however, seems to be the only practicable way of trying the experiment. The acid is very weak, as the acid in the roots is weak; but if salts, such as phosphate of lime, and others found in the soil,

are now strewn upon the bladder, they will in a short time begin to pass through it into the tube, being dissolved by the weak acid in its pores.

The acid in the roots acts, it is supposed, in a similar way, and thus the dissolved minerals are sucked in. But as before said, living things have more power than dead ones; so it may well be that roots, like lichens, dissolve more than the weak acid alone would do.

The roots take up what they themselves dissolve from the particles of soil immediately surrounding and closely touching them, and also what the water in the soil has dissolved for them, with the help of carbon dioxide and other gases.

The water thus taken up—for what is dissolved by the roots and what is dissolved by water and gas are taken up together—the water thus taken up is a very weak solution of various salts—phosphates and others—so weak that it may fairly be compared with ordinary drinking-water.

No water in nature is or can be perfectly pure, as has been said, because it is constantly dissolving something wherever it goes. And though even with what the roots have dissolved the solution is still so weak as to pass for ordinary water, yet it must be borne in mind that the roots are constantly sucking it in, and that the leaves are as constantly returning the water to the air—only the water, however. The salts remain behind and accumulate day by day.

The same sort of thing on a vast scale goes on with the rivers and the ocean. River water is generally tasteless, though it, too, contains various salts dissolved in it. This small proportion of salts is, however, being constantly poured into the ocean, while the sun is constantly

taking away by evaporation almost pure water. The salts, therefore, accumulate, and sea water is salt and bitter in consequence.

The salts left in a plant do not usually make it salt or bitter, because the quantity is altogether extremely minute in proportion to the plant's size; and as they are distributed through the whole of its substance, there is a continual demand for them while the plant is growing or putting forth fresh leaves.

But if a plant is stunted by drought it may become actually bitter. A cabbage, for instance, which has not reached perhaps a quarter its proper size for want of water, will be quite bitter; and the reason seems to be that the salts, which would have been enough for a large cabbage, are compressed into a very small one. Or, in other words, the roots have not been able to find enough water to dilute the food which they have gathered, as well as to keep pace with the transpiration of the leaves, and to allow of their proper growth.

QUESTIONS FOR REVIEW

1. Show how soils vary in their ability to suck moisture from the air or to keep it.
2. How do soils differ in their readiness to give up moisture? Illustrate.
3. How is the surface soil moistened in time of drought?
4. How do the roots vary in different kinds of plants?
5. Describe the character of a root.
6. Why is it necessary that soil should be both fine and well mixed?
7. Why is clay a poor soil for plants?
8. What is the character of the water taken up by the roots?
9. Why is the sea salt?

CHAPTER XI

FOOD FROM THE SOIL

It is but a very small part of their food after all which plants, generally speaking, draw from the mineral matter of the soil in which they grow; and yet this small quantity is not merely important, but absolutely necessary. It is dissolved by water and gases, and by the action of the plant itself, and is then taken up by the roots, especially the younger, finer roots, and root-hairs, by which it is passed on to the stem, and so is conveyed to every part, not only to branches, leaves, and buds, but also to flowers and fruit. Every part of a plant needs some amount of mineral matter, and the plant cannot obtain it without water, for whether dissolved by the plant's roots or otherwise, it is in each case taken up in very diluted condition; so diluted, indeed, that the water containing it is hardly to be distinguished from ordinary drinking-water.

The plant could not be sufficiently nourished by these very weak dilutions, especially while it is growing, but for the fact that it is constantly receiving them.

Perhaps one of the most striking examples of the way in which plants are fed by this very weak food is to be found among the sea-weeds. Many sea-weeds contain large quantities of iodine, which, like the rest of their food, they draw from the sea. With the smell of iodine we are all no doubt familiar; but if we mix one part of iodine with three hundred thousand parts of water we

entirely lose it; that is to say, no one of our senses is keen enough to detect it. We can neither see, nor taste, nor smell it. But of course it is there, and we can find it again by adding starch, which is turned to a brilliant blue by coming in contact with even this minute quantity.

But the iodine contained in sea-water is less even than this—it is less even than the hundredth part of this infinitesimal amount. And yet the sea-weed manages to extract it. And although plants take their mineral food in such weak dilutions that we cannot detect its presence either by taste or smell, and might be inclined to think that it can matter very little what it is, yet they are discriminating; and their roots have to some extent the power of choosing what they will or will not take up.

This is evident from the fact that plants growing side by side will take up different food, or take it in very different proportions.

There is, for instance, the common reed and the common species of moss, which both grow in bogs. The soil is dissolved by water and gases equally for both, and both take up a good deal of dissolved flint, or silica; but the reed takes up also a very small quantity of salt, a little more, but still a very small quantity, of iron, no soda, a little magnesia, and a great deal of phosphoric acid; whereas the moss, which grows close by, takes very little either of phosphoric acid, magnesia, or salt, but some soda, and much iron.

The same thing is also true of the farmer's crops, and it is for this reason that he varies them, not growing the same crop year after year, or even two years running, on the same soil, lest it should be exhausted and unable to feed them.

Corn crops, for instance, take up much flint, which goes chiefly to give the hard, glossy coating to their stems; and they want from a fifth to a tenth part as much potash. Turnips and beet, on the other hand, take in little flint, but more lime and potash; and turnips and carrots will use up the suphuric acid; while clovers want little sulphuric acid, but much potash, lime, and soda.

All plants need more or less of several mineral substances, and even when it is "less," they cannot do without this lesser quantity, be it never so small. When, therefore, we say that corn crops take up much silica, or flint, it is not at all meant that they do not take some proportion of lime, potash, soda, sulphur, iron, and phosphoric acid as well; for they use them all, in larger or smaller quantities.

The amount of each mineral taken up varies in different kinds of corn; wheat, oats, barley, etc., have all their special needs, and so, as stated, have different varieties of the same kind of corn. More than this, different plants of the same variety differ slightly in this respect, as if they had their own individual preferences; but the difference is very slight, and in plants of the same species the proportion always remains nearly the same.

And this is true, no matter where the plant may grow. If it grows at all, its ash, that is, the mineral substances which it has taken from the soil, will always be found to be pretty nearly the same; the proportion will be the same, that is to say, for of course, in unfavorable soil, the plant may be a dwarf. Grasses, for instance, which are like corn in taking in considerable quantities of silica, will take up just as much of this when they grow on the chalk soil of the downs as when they grow in a soil con-

taining much sand. Yet chalk, pure chalk, does not contain a particle of silica.

As before remarked, however, such a thing as a perfectly unmixed soil is hardly to be found anywhere. Even on the mountains there is rarely less than ten per cent of soil which has been brought from elsewhere, either by wind or water, or added to it by animals. So it is on the downs, and the grass finds there what it needs.

It would be rash to say of any plant that it will not grow on any soil until it has been tried; but plants certainly have their likes and dislikes in this matter, though sometimes a good climate will make up for poor soil.

Some plants have such peculiar tastes, or requirements, in respect of soils, that they must seldom, one would think, be able to gratify them; and one almost wonders where the seeds come from when the opportunity for growing does arrive.

Some, for instance, are never to be seen except after forest-fires; apparently because they require wood-ashes to grow in. Other plants have similar likings; and it was observed that after the fires of London and Copenhagen, plants of the same kinds grew among the ruins of both cities.

It is very remarkable, too, what slight, and even imperceptible, differences in the soil will make very great differences in the crops grown upon them. This is especially noticeable in the case of vines. Tokay wine, for instance, cannot be made except from grapes grown in the one district from which it takes its name. The vines may be grown elsewhere, but the wine is different. So, too, in France; vineyards growing side by side, and separated only by a narrow footpath, having the same aspect,

and apparently the same soil, and cultivated in precisely the same way, yet produce wine of quite different qualities and very different values.

Every crop takes away from the soil, not one mineral substance only, but several, in larger or smaller proportions; and the soil is to this extent poorer than it was before. If the crop is cut and carried, nearly the whole of what it has taken up is lost to the soil; in the case of turnips and other root crops, the whole plant is taken away, and the loss is so much the greater.

A meadow which is mown by a machine, too, loses more than one mown with the scythe, as the machine cuts closer; and horses are said to take more from a meadow than either sheep or cows, for a similar reason, because they are closer feeders. But where a crop is consumed by animals, it is not all lost to the soil. On the contrary, so much is returned to it in their droppings, and returned, too, with increased fertilizing powers, that the land is actually benefited, and needs no other manure; whereas hay-meadows cannot go on bearing crops year after year without being manured, or top-dressed, to make up for their yearly loss.

It is a different matter, of course, where the crops grown by nature are concerned; for these, being neither machine-mown nor scythe-mown, so far from rendering the soil poorer, really do much to enrich it.

Herds of wild cattle may eat off grass and herbage, as they did for ages before man came and took possession of their grazing-grounds, but they manured the soil in return.

The same is also true, though in a different way, of the plants themselves. If they are left alone, they return to the soil all that they have taken from it, and more

besides. For they give to it, also, that food which they draw from the air, of which we have yet to speak.

The roots of a tree are constantly bringing up supplies from the deep subsoil, which, when the leaves fall, are added to the surface-soil; and the ancient forests of North America, after flourishing for ages, and producing enormous quantities of timber, left the soil, not impoverished, but so rich that it was hardly exhausted by a whole century of wasteful farming.

The "yellow earth" of China, a deposit of very great extent, is believed to consist very largely of the ashes of plants, accumulated during more generations than one can attempt to realize, for in some parts it is more than fifteen hundred feet thick.

It is the long-continued course of this green-manuring which has so largely contributed to produce the extraordinary fertility of the "black earth" of Russia and the region of Manitoba. And so, too, with the pampas of South America, a still more interesting example, because the process is going on under our eyes.

In the winter Captain Head found the "thistle" part of this region looking something like a rough turnip-field intermixed with clover, so large and luxuriant were the leaves of the thistles—really wild artichokes. In the spring, the thistle-leaves had spread, and had overgrown the clover, but still had the appearance of a rough crop of turnips. Less than a month later, however, they had shot up in the most surprising manner, and were in full bloom. They were now ten or eleven feet high, and formed such a close, impenetrable barrier on each side of the track that nothing whatever could be seen in any direction. The growth was so amazingly rapid that an

army might easily have been hemmed in unawares by the thick, strong stems.

Before the end of the summer there was another change. The heads drooped, the leaves faded, the stems turned black and rattled in the breeze until they were blown down by the periodical hurricane, when they quickly rotted away, and the strong, luxuriant clover rushed up again.

The artichoke, as well as its near relation, the true thistle, requires a rich soil, and would be an exhausting crop if it were cut and removed, because it takes so much food; but as the roots penetrate to a great depth, it benefits the clover, and the clover in its turn enriches the soil for the thistles.

Clover is found, indeed, to be such a beneficial crop that farmers in America sometimes grow it in alternate rows with wheat, and this is also the only kind of green-manuring commonly practiced in England. It is in warm countries, where growth is rapid, that this sort of manuring is chiefly useful; and in the Azores, yellow lupins are very frequently sown among the corn and plowed in when it is reaped.

Lupins are plants which are especially active in dissolving mineral matter; and the same is true of other members of the large family of leguminous plants to which they belong—clovers, vetches, beans, peas. Moreover, not only these but other plants dissolve more food than they need for their own immediate use and leave it in the soil, making it easier therefore for their successors to find nourishment.

This, then, is another important service rendered by the wild crops which have grown for ages past on what

are now the best soils in the world for the farmer's purposes. Whether these crops be trees, or shrubs, or herbage, they have not only brought subsoil up to the surface, but they have, at least in some cases, dissolved more than they have used, and have left it all ready for the crops which follow to make use of.

But even this is far from exhausting their very important list of services. Indeed, the most important of all has yet to be mentioned.

Animals cannot live either upon mineral matter or upon gases, though they need both, until these have been made ready for them, which they must be in the first instance by vegetables.

Plants are more independent, for they can make use of mineral matter, and of gases; but they, too, need a little organic matter as well, either animal or vegetable. Some plants need more than others; but no soil is really fertile which does not contain at least some small amount. As has been shown, however, no soil is absolutely lacking in this important ingredient, for wherever plants have grown, or animals, however lowly, have lived, there they have left their remains.

Why plants should need organic matter is another and more difficult question, which seems to be at present unanswerable. All organic remains, of course, contain some mineral matter; but this the plant can get from the soil. They all also contain much carbon; but this the plant can get without their help from the air. And finally, they all contain nitrogen in some one or more of its compounds; and it is this nitrogen which the plant wants, and cannot, apparently, get, in sufficient quantity, except from organic matter.

There is an abundant supply of nitrogen in the air,

however, and why plants cannot help themselves to it—when they can, and do, take up carbon dioxide from the same source—one cannot say; but such is the fact. Both are gases; and as nearly four-fifths of the air consists of nitrogen, there is certainly no lack of it. However, the plant takes the one up by its leaves, as will be seen in the following chapter, and does not take the other, much as it wants it.

All animal and vegetable matter, then, contains nitrogen; and as all plants, whether lichens and mosses, or oaks and palms, must have some amount of it, they most of them get it from this source—the decayed organic matter in the soil.

But there are others which get it equally well from living matter. The mistletoe and other similar plants get this, as well as other food, from the living trees or plants upon which they grow. And other plants, again, sometimes turn the tables on the animal world, and actually devour living insects.

The plant called Venus's fly-trap is one of these insect-eaters, and a very curious plant it is. Its leaves end in two lobes, on each of which are three delicate hairs, so placed as to form a triangle, and in such a position that it is almost impossible for any insect alighting upon the leaf to help touching them. As long as the leaf only is touched, no harm is done, but if but the tip of one of these magic hairs be touched, the leaf closes instantly upon the victim, and does not reopen until it has sucked it dry. The trap will close equally upon a dead, dry fly, or any other substance placed upon it, but it reopens almost immediately, when the plant, by some mysterious instinct, discovers that the morsel is indigestible.

A large blue-bottle will be seized at once, and squeezed so tight that escape is impossible. But a meal of this sort seems to be very satisfying, for in one instance the leaf did not open again for twenty-four days, and when it did, though the dry remains of the fly were removed, no attempt to catch more was made until several days later. There was a similar result in the case of caterpillars, raw meat, and spiders. All are digested by means of an acid which the leaf pours out upon them.

It is a curious fact, that the dropping of water upon the trap does not make it close, unless the sun is shining, or has been shining immediately before, upon it. In this case, the plant, not being prepared for rain, seems to be for the moment deceived. Rain usually comes when the sky is cloudy, and then the leaf, knowing apparently what to expect, takes no notice. If it closed for rain, it would of course often lose a meal.

One of these plants, having six leaves, has been known to comfortably digest twelve flies, or twelve good-sized spiders, at once, one for each lobe, after which it was satisfied for some time.

The bladderwort has been seen to catch newly hatched roach and also worms, by means of its bladders; and the butterwort catches its victims by means of the sticky glands with which its leaves are thickly covered, rolling up its edges over them, and undoubtedly eating them.

The various pitcher-plants also feed upon the large number of insects drowned in their receptacles, which are from two or three to as much as eighteen inches deep, and always contain water.

But whether or no many plants are actual flesh-eaters, it is certain that they all need nitrogen; and other food,

however abundant, will not be enough for them, or enable them to grow properly, if they be stinted in this respect. Their more usual way of obtaining it, however, is from the soil, or from the air; but in neither case can they take the pure gas itself; it must be in the form of a compound before they can make any use of it.

By way of trying whether plants could do without nitrogen, other than that by which they are surrounded in the air, three pots were filled with a soil of sand and brick-dust, from which all animal and vegetable matter had been removed. A couple of sunflower-seeds were planted in each, and all three were watered with pure, distilled water, containing no food whatever.

The plants in the first pot turned out mere dwarfs, as was to be expected; those in the second were not much better, though they had had a small quantity of clover-ashes given them; but those in the third were almost as large as the finest specimens grown in the garden, for they had been supplied with a compound of nitrogen, in the form of potassium nitrate; and while the two first had managed to get only about the thirtieth part of a grain of nitrogen from the air, these had taken sixty-six times as much from the soil. The quantity is still very small, of course, only two grains and a fifth; but it strikingly illustrates the immense importance of small, and even minute quantities, since it made the whole difference in the growth of the plants.

The dwarf sunflowers obtained their small fraction of nitrogen from the air; but this is no contradiction to what has been previously said, for they did not take pure nitrogen, but ammonia, which is a compound of nitrogen and hydrogen.

There is always some very minute quantity of ammonia in the air—about one part in a million—and there seems to be no doubt that plants can and do take this up by their leaves, for they thrive all the better when the quantity is artificially increased. But they take it up also, and in larger quantities, by their roots, when it has been absorbed by the soil, or brought down to it by rain, snow, and dew.

The quantity of nitrogen thus washed down in combination with hydrogen in the course of the year seems to be from about two pounds to nearly twenty-one pounds per acre; but the average is about four and one-half pounds to the acre—four and one-half pounds spread over an acre of ground! Considering that there are seven thousand grains in a pound, and that the sunflowers, even when they had more within reach, took up little more than a grain of nitrogen apiece, perhaps the quantity may not sound so very small.

But an acre of wheat, yielding twenty-eight bushels, takes up about forty-five and one-half pounds of nitrogen; while an acre of clover uses one hundred and eight pounds!

And even this does not at all represent the whole of what is required; for the roots, however many, cannot possibly be in close contact with all parts of the soil at once, and they can no more make use of all the nitrogen than they can of all the mineral matter, or all the moisture; so that of this, as well as of the rest, they need much more than they can actually use.

An acre of soil, one foot deep, weighs some four million pounds; and just a few pounds of nitrogen equally mixed in this would be almost as difficult to find as a

needle in a haystack; and even if there were actually as much as the crop required, the roots could not reach it.

A heavy wheat crop needs, therefore, nearly three hundred pounds of nitrogen to the acre, or about six times as much as it actually takes up. And this it certainly cannot get from the ammonia in the air, or from that which is washed from it into the soil.

But when organic matter decays, whether it be animal or vegetable, the nitrogen contained in it combines with other gases to form not only ammonia, but also nitric acid.

Much of the ammonia streams off into the air, but the nitric acid remains and combines with potash, soda, lime, magnesia, or iron, with which it forms nitrates. These nitrates are easily dissolved, and it is from them that the plants obtain their nitric acid—very much diluted, of course, as is all the food which they take from the soil.

As already remarked, plants have the power of decomposing such salts, taking one ingredient and leaving the other. The sunflowers which throve so well in the experiment described were supplied with potassium nitrate, and from this they were able to extract the nitric acid which they needed.

Nitrates are very soluble, and in damp soil they are formed and dissolved so quickly as seldom to be visible. But it is not so in regions where rain falls either at certain seasons only, or very rarely. The most fertile soils of Bengal, for instance, are often covered during the dry season with a white crust of some of these salts, chiefly potassium nitrate, otherwise called nitre and saltpeter. The crust vanishes as soon as the rain comes, being dissolved and washed into the soil, which is so rich as to bear two or three crops a year.

Wherever these nitrates are formed, whether, as in England, they are dissolved almost at once, or whether, as in dry lands, they accumulate and encrust the soil, they are formed by the decay of animal and vegetable matter. And what, it may be asked, causes this decay? Not the action of the air; for in perfectly pure air organic substances do not decay. The change is brought about by the action of living organisms, invisible, but very potent in their effects.

We have all heard enough about "germs" of late to know that they swarm in the air; but they also swarm in all the moist places of the earth. Some few classes of them are dangerous to man, and produce diseases of various kinds; others are not only harmless, but productive of the greatest good.

All decay, fermentation, or putrefaction, whichever we call it, is their work; and when we say "work," all that is meant is their living, growing, multiplying, which they cannot do without feeding. There is an immense variety of them, and they produce different results, according to their different modes of feeding. The yeast which is put into dough, the "mold" which grows upon paste, or jam, are all of similar nature, and all produce alterations in the substance which they attack. When we like the result of these alterations, we call the process "fermentation"; and when we do not like it, we call it "putrefaction"; but both are substantially the same, for both are the result of decomposition. Grape-juice, apple-juice, and wort are converted by these "ferments" into wine, cider, and beer respectively; and another ferment again alters wine yet further, and turns it into vinegar.

It is these living organisms which bring about all decay

of animal or vegetable matter, whether in the soil or elsewhere.

Their work in the soil seems to go on chiefly in the upper nine inches, and most rapidly when the weather is warm and damp.

The multitudes of leaves drawn in by worms, the old roots of former crops, or green crops which have been grown only that they may be plowed in—all are decayed, and so converted into food, of which the next crop can avail itself.

As has been more than once remarked, all soils contain more or less organic matter; but unless the amount is very large, as it is in the Russian black earth region, Manitoba, and elsewhere, not much of the nitrates formed by its decay will be left in the upper twenty-seven inches of the soil after a crop of corn has been grown in it. Organic matter there will still be, but decay is gradual, and nitrates take time to form; so the farmer must supply the want in one way or other.

In former days, till within the last century in fact, his way of doing so was simple. He merely plowed up the field, and let it alone to recover itself; in other words, he allowed it to lie fallow.

And what goes on in a fallow field? Generally speaking it is, or was, both plowed and harrowed repeatedly, so that the soil might be exposed as much as possible to the action of the air and rain, by which the mineral matter would be dissolved ready for the next crop. Then in the winter the soil would be yet further broken up by the freezing of the moisture in its pores, which would separate grain from grain, reducing it to powder in a way that no plow or harrow yet invented can do. The crumbling of

the soil would make it yet more easily dissolved by water, as well as more easy for roots to penetrate; nor must it by any means be forgotten that while the land lay idle the worms were busy, turning it over, also, grain by grain, and enriching it as already described. And though the farmer did not sow it, seeds were sown by the wind, and a crop of weeds was certain to spring up, whose half-decayed leaves the worms would drag into their burrows. The whole wild crop, too, would be plowed in, and with the roots of the farmer's last crop, would be gradually decayed. The soil when damp would absorb ammonia from the air, and ammonia would also be brought down by rain and snow, and converted into nitric acid, which would combine with some of the minerals already mentioned; and in this way, as well as by the decay of the organic matter left in, or added to, the soil, a fresh supply of nitrates would be prepared.

QUESTIONS FOR REVIEW

1. Illustrate the fact that plants absorb mineral food in very weak dilutions.
2. Why does the farmer have to vary his crops?
3. How differently is the soil affected by the various ways in which the crops are disposed of?
4. What substance is it which plants have to get from organic matter?
5. How do some plants secure this from living matter?
6. How is the soil provided with nitrates?
7. What causes the decay of organic substances?
8. What processes go on in a fallow field?

CHAPTER XII

LEAVES AND THEIR WORK

All the plant-food which we have yet considered is drawn from the soil, with the exception of the minute quantity of ammonia taken in by the leaves from the air. But this latter is far from being all that the leaves contribute to the food-supply.

The roots furnish food from the soil—mineral and organic matter; and the leaves furnish food from the air—the carbon, which makes up about half the dry weight of a plant—half its weight, that is, when all the water has been removed from it. Roots and leaves, therefore, supply about an equal amount of food.

But the leaves do more than merely supply food; they prepare it for the whole plant, both that which they themselves take up, and that which is procured by the roots. Leaves are the food-manufacturers; and it is they which combine the various materials, and distribute food to the several parts.

Nitrogen, the food derived from organic matter, which we have last considered, is needed in some combination or other by all parts of a plant, but especially by the seed. No one needs to be told that grain is more nourishing than straw; but the reason why it is more nourishing is that it contains more nitrogen, in the form of nitrogenous or albuminous compounds, commonly called albuminoids, because they resemble the albumin, or white,

of an egg. There is albumin in the liquid part of blood, and there is albumin in the seeds and juices of plants. There is fibrin in flesh and in the thick red part of blood; and there is vegetable fibrin, a sticky substance usually called gluten, in flour. There is casein in milk and cheese, and there is casein in beans.

These various substances are all jelly-like, and are very similar in composition, whether they are obtained from animal or from vegetable matter. They are called nitrogenous because it is the nitrogen they contain which gives them their especial characteristics and value as food; but the nitrogen in them forms less than a seventh part of their substance, more than half of which consists of carbon. In addition to this large amount of carbon, most of the nitrogenous compounds contain sulphur, besides hydrogen and oxygen, and most of them phosphorus as well. They could not therefore be formed without the help of mineral matter from the soil, and of carbon from the air; the nitrogen being obtained both from the nitrates in the soil and from the ammonia in the air.

All the corn crops, as well as the clovers, beans, peas, and other leguminous plants, require much nitrogen, especially when their seeds are forming and ripening; but by the time they have done blossoming, they have taken up all they want, and it is being prepared and compounded by the leaves, to be gradually passed on by them to the growing seeds as they need it. Grass, therefore, is not cut for hay until after it has blossomed, because it then contains most nitrogen and is most nutritious. For the nitrogenous compounds are the flesh-forming part of all food, animal or vegetable.

They are very much alike in composition, as has been

said, and substances which are closely similar may be obtained both from a beefsteak and a cauliflower; from the white of an egg and from a cabbage; from milk curd, and from peas and beans, of which the Chinese do actually make a vegetable cheese.

Quantity for quantity, a cabbage is, indeed, less nutritious than the white of an egg, but the cabbage contains a similar substance. It would, however, be necessary to eat a much larger weight of cabbage to obtain as much flesh-forming food as is contained in an egg.

And then, again, though the nitrogenous compounds obtained from flesh and vegetables are similar—so closely similar even as to appear almost identical—they are not absolutely identical, and it would be rash, therefore, to conclude that they are equally nutritious. For, if one thing be more plain than another, from what has been said in the previous pages, it is the immense importance belonging to little things—to trifles so minute as almost, or quite, to escape detection.

Let us remember the vineyards growing side by side—the treatment the same, the soil so apparently the same, that the difference cannot be detected—and yet the wine from the one is worth, and fetches in the market, twenty times as much as the other! The vines being of the same species, and all other things being equally enjoyed by both, it follows that the difference in quality must be caused by some slight difference in the soil, which is so slight as to be undiscoverable.

If, therefore, so slight a difference in the vine's food can make so large a difference in its produce, it seems altogether rash to conclude that the cheese of beans is as

nutritious as the cheese of milk; or that it makes no difference whether one dines on cauliflower or beef.

All plants do not contain an equal amount of the nitrogenous compounds; and even the same plant contains very different quantities in different parts, and also at different stages in its life.

Leaves and stalks are less nutritious than seed, and the seed itself is more nutritious when it is ripe, as it is then that it contains the largest amount of nitrogen. Ripe ears of maize, for instance, contain ten times as much nitrogen as green ears; but even then they contain less than either rye, oats, or wheat, and less than half the amount contained in peas, beans, or lentils. Lentils, indeed, are among the most valuable of the seeds used as food, for nearly a fourth part of their substance consists of albuminous, or nitrogenous, compounds. As for potatoes, they are very low down in the scale of food, for they are chiefly water, and the amount of flesh-forming food which they yield is only two parts in a hundred, less, that is, than meadow-grass before it has blossomed.

We must now look a little more closely at the work done by the leaves, for it is they, as has been said, which supply the plant with carbon. Carbon is wanted for the nitrogenous compounds; carbon is wanted for the plant's skeleton, and for its wood; carbon is wanted for the manufacture also of starch, gum, sugar, oils, acids, and the various aromatic compounds to which plants and flowers owe their fragrance.

And this carbon the leaves have no difficulty in providing, so long as the roots do their part; but if they fail, the leaves must fail, too. For the plant is a whole, a

body, of which every part is dependent upon the rest. But while the roots can do their work in the dark, the leaves are perfectly helpless without light.

Give the plant light, however, together with the proper food which the roots collect from the soil, and then the leaves have no difficulty in adding the carbon which is their share.

And why, it may be asked, should they have any difficulty? Since the whole plant wants it, and has to get it through the leaves, surely it would be more strange if the leaves could not find it, since they live in the air, where it is.

Perhaps; but the proportion in the air is extremely small, though the amount sounds large; and leaves cannot wander in search of food, as roots do. The food must come to them, as they cannot go to the food. Carbon exists in the air, combined with oxygen, as the gas carbon dioxide, or carbonic acid; and there are about three billion four hundred million tons of the gas in the atmosphere of the whole globe. The figures convey little to one's mind, but at all events, the amount sounds comfortably large—sufficient, at least, to preserve the vegetable world from all risk of a dearth of this species of food.

And yet it has been calculated, that if used at the present rate, the whole of this enormous supply would be exhausted in about a hundred years, after which not so much as a blade of grass could exist until the supply were renewed.

Let us put it in another way. The amount is large in itself, but it is enormously diluted—so much diluted, indeed, as to be hardly reckoned at all; that is, in speaking of the air, we commonly say that it consists of about four-fifths nitrogen and one-fifth oxygen, leaving the car-

bon dioxide out of the account altogether. For except in confined spaces, and under special circumstances, one part in twenty-five thousand is all the carbon dioxide that the air contains, so vast is the space through which the gas is distributed. There is just enough carbon dioxide in the air to furnish twenty-eight tons to every acre all over the globe—twenty-eight tons of gas, or eight tons of carbon!

But an acre of beech-forest would use up the whole of this allowance in about eight years; and it would not last an acre of bananas much more than one year.

All plants do not, it is true, use up carbon at these rates; but it is evident that the supply needs pretty constant renewing. And it is renewed day by day, hour by hour; nor, so long as animals breathe, and fires burn, and vegetable matter decays, is there any danger that the supply will run short.

Whenever carbon unites with oxygen it is what we call burned, and carbon dioxide is produced. The carbon disappears, but it is not destroyed—it has only been made invisible by combining with oxygen. Whenever, therefore, animal or vegetable matter decays, the carbon which it contains is slowly burned, and the gas passes off into the air as it forms, unless prevented, as it is, in a great measure, when produced underground.

Again, when animals or plants breathe, the oxygen which they inhale unites with and burns part of the carbon of their food, and the gas is breathed back into the air. The air we inhale contains but one part in twenty-five thousand of carbon dioxide; but the air we exhale contains much more—from three to six per cent. Plants, however, breathe very much more slowly than any warm-

blooded animals, and give off less carbon dioxide in proportion.

Whenever carbon is bu:ned by combining with oxygen, whether in food, coal, wocd, gas, oil, candle, or in decaying vegetable-matter, there carbon dioxide is formed. It is being constantly poured into the air, therefore, by men and animals, by the chimneys of factories and houses, by volcanoes, and by the soil.

But it is not produced in anything like equal quantities in all parts of the world. Very little is returned to the air above the ocean, and t'.at little chiefly by passing vessels; and as there is more ocean than land in the southern hemisphere, much less is produced there than in the northern hemisphere, which is chiefly land.

Then, again, the eastern hemisphere is much more densely populated than the western, besides having, of course, many more factories, furnaces, and engines of all sorts, which are constantly burning carbon. It might seem not improbable, therefore, that some parts of the world, such as the islands of the Pacific, should be at times in danger of not having carbon dioxide enough to supply the wants of their vegetation, especially when we consider that bananas, which need such large quantities, form an important item in their crops.

But the fact is not so; for the supply is equally distributed. More fires are kept burning, and more carbon dioxide is produced in winter, when the trees are leafless and do not want it, than in the summer, when they do. And yet we are not choked by it, or even inconvenienced by it, in the winter months, so it must be got rid of somehow. For if there were two per cent in the air, we should have severe headache, and ten per cent would

suffocate us. What, then, becomes of it? Roughly speaking, we may say that the carbon dioxide produced during the winter of the north goes to feed the vegetation of the south—the thistles, clover, and grass, for instance, of the pampas, which are flourishing in all their luxuriance while winter prevails with us. And it goes, to some extent, at least, because the leaves of the southern hemisphere draw it thither.

The ocean of air which surrounds the world is not, it must be remembered, a compound, but a mixture. If we could see it we should find oxygen, nitrogen, carbon dioxide, ammonia, all perfectly mixed, but perfectly distinct. The combination of two gases, oxygen and hydrogen, makes water—a liquid entirely different from both; but there is no such combination and alteration in the gases of the air. Each keeps its own character; but though all are of different weights, they are so thoroughly and perfectly mixed, that except under special circumstances, there is but little appreciable difference in the air of different parts of the world.

Carbon dioxide is the heaviest of these gases, and it is more than twice the weight of the mixture of these gases which we call the air. Where it is poured out from cracks in the earth, as it is largely in some volcanic districts, its weight keeps it down for a time near the ground, but gradually, in obedience to a mysterious law, it rises and spreads through the air. Its weight draws it down to the earth, or more correctly speaking, the earth attracts it to itself more than it attracts either oxygen or nitrogen. It is heavy, because the earth attracts it, just as a stone is heavier than a feather. But it rises.

We should be surprised to see a stone thrown from our

hand continue to mount upwards instead of falling to the ground, but this is precisely what carbon dioxide does, and we can but state the fact without explaining it. Gases, no matter what their weight, are obliged to mix one with the other.

Put into a bottle first some heavy carbon dioxide, then some oxygen, which is lighter, nitrogen, which is lighter still, and lastly, hydrogen, the lightest of all, which is so light that it has to be poured upwards, and though at first the heaviest gas will be at the bottom, before long all will be perfectly mixed, and there will be as much hydrogen at the bottom as at the top. Carbon dioxide moves more slowly than hydrogen, owing to its weight, but move upwards it will, and that without any shaking.

All, or part, of the carbon dioxide might, however, be removed from this mixture without affecting the other gases, if a piece of caustic potash were introduced; for this substance has the power of attracting and absorbing this particular gas. Each of the other gases might also be removed by similar means, one by one substance, and another by another.

Leaves, then, act upon carbon dioxide in some such way as caustic potash does. They attract it to themselves and absorb it; but by so doing, they are constantly diminishing the amount of the gas in the air immediately surrounding them; and as, according to the law of their being, gases must mix equally one with the other, more carbon dioxide flows in to supply the place of that which is absorbed. Streams of the gas are therefore constantly flowing towards each leaf, even when the air is still; when there is wind the whole air is, of course, in motion.

We have now to see what becomes of the carbon diox-

ide when the leaves have taken it up. As has been said, in most plants nearly one-half the dry substance left when the water is removed consists of carbon, of which charcoal is an impure form. Carbon enters into the composition of every animal and vegetable substance, no matter how minute. It is to be found in every part of a plant from the root upwards, but especially in the seed. In the grains which we use as food the quantity of carbon amounts to some forty or fifty per cent of the whole; and though the carbon compounds are not, like the nitrogenous compounds, flesh-formers, they are equally important as fat-formers, and as supplying fuel to maintain the heat of our bodies. The carbon of our food is oxidized, burned, by the oxygen of the air we breathe; heat is thus produced, and the greater part of the carbon is given back to the air as carbon dioxide.

One pound of wheat flour contains about nine and a half ounces of starch, and starch is a compound of carbon, oxygen, and hydrogen; but it also contains two ounces of gluten—one of the nitrogenous compounds—and half of this is carbon; and besides these it contains smaller quantities of sugar, gum, and fat, and these are all carbon compounds; so that altogether the pound of flour contains some seven ounces of carbon.

Some of the palms, as the sago palm, use very large quantities of carbon in forming the starch of their pith: one tree, for instance, often yielding the extraordinary amount of eight hundred pounds of starch. All the sugars, oils, gums, caoutchoucs, of the vegetable world, contain large quantities of carbon, and so also do the fibers of cotton, flax, hemp, and others.

But as already said, carbon forms part of the struc-

ture of every portion of a plant from root to seed, and it enters largely into the composition of the skeleton, or frame-work, both of stems and leaves; for a plant's skeleton consists of fiber, identical in composition with the fibers of the cotton and other plants used for weaving purposes.

Now both the skeleton and the flesh of a plant, every part of it, indeed—roots, stems, leaves, flowers, fruit, seed—consists either of a single cell, or of an assemblage of cells, which may be compared with the cells of a honey-comb, except that they vary extremely in size and shape.

Some cells are so minute as to be altogether invisible to the naked eye; as for instance, the spores of lichens and fungi, the "germs" already mentioned, and certain minute water-plants, each and all of which consist of a single cell, filled, like the honey-cells, with more or less fluid contents.

But the cells in the flesh of a lemon are gigantic by comparison, being half an inch long; the cells of fibers are often much longer than this, and there are cells of all sizes between these, the most usual size being from $\frac{1}{1200}$ to $\frac{1}{200}$ of an inch across. Cells are of almost every possible shape, too—globular, square, six-sided, twelve-sided, or quite irregular, with their outlines beautifully zigzagged or waved. But whatever their shape and size, their walls, thick or thin, are composed of the skeleton material mentioned above, which is called after them "cellulose."

This material, like cotton and other fibers, is composed in great measure of carbon, and as all plants increase in size by the multiplication of cells, it is evident that they could not grow at all in air containing no carbon dioxide. Neither can they grow if deprived of their leaves, for

these are the chief manufacturers of cellulose and other food. A tree stripped of even half its leaves will be unable to make much wood, though it may manage to live.

The skin of a leaf usually consists of a single layer of cells, not green, but colorless and transparent, and beneath these are other cells containing, besides other things, "leaf-green," or coloring matter. It is in these lower cells that the manufacture of the plant's food is carried on; and though the process cannot be explained, one or two facts are certain—it cannot, in most plants, go on without light, or in any without the leaf-green.

The gases of the air are able to pass through the cell-walls, both in and out. It must not be forgotten that plants need air for breathing, as well as carbon dioxide for food; and though they breathe as well as feed by means of their leaves, the two processes are quite distinct.

What the plant does with the carbon dioxide is to separate the carbon and keep it, and to let go most of the oxygen. The two have to be torn asunder, and this is done in the cells containing leaf-green. But the leaf-green itself cannot be developed either without light, or without iron; and when developed it cannot act in darkness.

For the supply of iron the leaves are, of course, dependent upon the plant's roots, and if the roots cannot find it, the leaves and young stems remain yellow or colorless. Compounds of iron are, however, so very general in all the rocks composing the earth's crust, that it is almost impossible to find any soil quite without them.

But the iron may be taken away by artificial means, and when this is done the leaf-green turns yellow, as human beings do when their blood contains too few red

particles, and for precisely the same reason. Both stand in need of iron. Iron oxide is reddish when it contains the full amount of oxygen possible, and green when it contains less. Give the plant iron and keep it in the light, and the grains of leaf-green at once begin to turn their proper color, and tiny grains of starch form within them.

A very little light, barely enough to read by, will be sufficient to make a plant begin to turn green, but not sufficiently green to enable it to separate the carbon; and therefore in dim light no starch grains can be formed. In ordinary daylight, however, whether the sun be shining directly upon the plant or no, these starch-grains are being continually produced; but the brighter the light the more briskly the manufacture goes on, up to a certain point—provided, that is, that the air contains carbon dioxide wherewith to furnish the necessary supply of carbon. If it does not, no starch, of course, can be formed, no matter how bright the light, or how green the leaf-green.

But all air, unless artificially deprived of it, contains enough to furnish what the plant requires in this respect, thanks to the supplies which are being constantly furnished to it. This is taken up not only by the leaves, but by all the green parts of a plant, leaves, buds, stems, and fruit, so long as these remain green; for it is only in the cells which contain leaf-green that starch is manufactured from the gas. These green cells lie immediately underneath the thicker-walled but transparent cells of the surface which compose the skin; and through the skin the gas finds its way into them.

The leaf-pores, by which water escapes, are openings in the skin formed by two curved, lip-like cells, which gape open in hot, bright weather, and close more or less

in rain, damp, and darkness; and it is when they open most widely that the manufacture of food goes on most briskly. For it is then that most carbon is separated, and most food is pumped up from the roots, as that is the time when the plant transpires most, and in this way both kinds of food are received together. When there is much transpiration, and water containing dissolved food is pumped up rapidly, then also much carbon is received, and *vice versá*.

Such plants as the cactus, which have no leaves, very few pores, and skin so thick and leathery that evaporation is prevented, transpire very little, and grow, in consequence, very slowly. The tall torch-thistle cactus of Mexico is said to take some hundreds of years in attaining its full size; whereas the thin-leaved gourd of the East is noted for its very rapid growth.

How the food from the soil and the food from the air are combined, and distributed from the leaves to all parts of the plant, is unknown; but from them each part does receive its due share of nourishment, one more of this sort, one more of that.

But without the leaves no food can be prepared, except where the stems take their place; and without light the leaves have no power to act. Hence the plant's whole life depends upon the sun.

In the autumn, when the plant has finished growing, no more leaf-green is formed, and the leaves begin to change color; for instead of manufacturing food, they are giving up their own stock to feed the young fruit.

Some plants, such as lichens, copper-beeches, and others, might be supposed to possess no leaf-green, because it is not visible; but they have it all the same; it

is merely concealed from view, hidden by other coloring matter.

But some plants never have any leaf-green under any circumstances, and therefore, being non-manufacturers, they have to live by the labor of others. Among these are the fungi, which grow and feed entirely upon organic matter, animal or vegetable, and are independent of the light. Mushrooms, for instance, may be grown in cellars; toadstools spring up in the night; for their food of all kinds—mineral food, nitrogenous compounds, carbon compounds—has been made ready for them in the light, by the dead vegetable matter upon which they grow. Perhaps it is the fact of their not having any work to do which enables them to grow with such extraordinary rapidity, as they devote all their energies to feeding and increasing in size. The cells of the puff-ball, for instance, multiply at the rate of three or four hundred million in an hour, and the plant will attain the size of a large gourd in a few days. The curious brown bird's-nest orchis is another plant which has no leaf-green, cannot provide its own food, and lives upon dead vegetable matter.

But there are other plants devoid of leaf-green, which prey, not on the dead, but on the living; sucking their juices, and profiting by their labors in earth and air. Among these may be mentioned the broom-rape, a brown, uncanny-looking plant, which attaches itself to the roots of living plants, clover, and others, and draws all its nourishment from them.

In one way or another, then, all plants obtain carbon; and when they have to do it by their own exertions they must have leaf-green, and they cannot usually have leaf-green without light, or in any case, without iron.

But, it may be said, seeds, most of them, begin to grow in darkness, underground, and so do bulbs; and they are usually pale yellow at first. If they have no leaf-green, as they evidently have not, then, if cells cannot be multiplied without carbon, and carbon they cannot get for want of this leaf-green, how do they manage to grow?

In the same way that other plants do which are also without leaf-green. They make use of the carbon stored by others; that is to say, they live for a time seedlings, upon the material stored in their seeds—bulbs, upon the material stored in the bulbs, which are buds, not roots—all of which has been prepared by means of leaf-green, and in the light.

In the case of bulbs, the leaves go on collecting food long after the plants have done flowering, in readiness for the blossoms of the next spring; and if the leaves are cut off before they have finished their work, the bulbs shrivel, and have not the means of supplying next year's blossoms at all. The autumn crocus comes up and blossoms without its leaves, but it is dependent upon them for the means of putting forth its blossoms, for the leaves have been busy months before, in the spring, storing the necessary material in the bulbs.

Seedlings, in like manner, when first they germinate under the soil, before they are provided with leaf-green, live upon the food stored up within them; but if, when this is exhausted, they are still kept in darkness, they will not only remain yellow, but will lose instead of gain in weight, and that though their roots may be busy collecting food from the soil.

But why, it may be asked, should they lose in weight? Without carbon they cannot, of course, use the food from

the soil; they cannot grow; but provided they have water, why should they not remain as they were? What are they doing to make them lose weight?

Well, they are doing just what all living things do, and must do, if they are to remain living; they are breathing—breathing as animals do, though they have no lungs, and though they breathe very much more slowly; that is to say, they are taking in air.

In breathing, as has been said, part of the oxygen of the air inhaled combines with and burns up part of the carbon taken in as food, converting it into the gas carbon dioxide, which is breathed back into the air. Warm-blooded animals breathe much more vigorously than plants do, but the process is the same in both.

Plants, however, breathe more or less through their whole surface, though chiefly through their leaves, and from the leaves, the air finds its way to every part.

Probably the breathing of plants may be fairly compared with the slow breathing of cold-blooded animals; but though feeble it is always going on, night and day, in light and in darkness, though more vigorously in light; and therefore, as the stock of carbon is gradually burned or oxidized, and breathed out, if it is not replenished it must be gradually exhausted, and the plant must lose weight.

To prove this, two beans of nearly equal weight were planted at the same time, one being kept in the dark, the other in the light. At the end of twenty-six days it was found that the seedling kept in darkness weighed more than a third less than the original bean, and the other weighed more than a third more. The one had breathed away some of the carbon contained in the thick seed-leaves

without being able to extract any from the air to feed upon, while the other had obtained food enough for growing and breathing, too.

There is some difference in the breathing of the leaves and the blossoms of a plant. The blossoms breathe faster than the leaves, especially when they are just opening; and they are therefore slightly warmer—in some cases, indeed, so warm that the heat may actually be felt! And the same is true of sprouting seeds when there are many together. The sprouting barley, for instance, from which malt is made, gives off quite a high degree of heat.

As the plant, like the animal, must breathe in order to live, it must needs have a constant supply of air for breathing, as well as feeding, purposes. And this air is necessary, more or less, not only for leaves and blossoms, but for all parts, including stems and roots. It breathes through all, though chiefly by its leaves and blossoms and the roots are always breathing out carbon dioxide into the soil. If the soil be too close, or baked on the top, the roots cannot get enough air to breathe properly, and the plant is sickly. And the same thing happens when soil is piled up round the stem, for the air is then kept away both from it and from the roots, and many a tree has been killed in consequence.

QUESTIONS FOR REVIEW

1. Name some of the most common nitrogenous substances. Why are they so called?

2. Why is it rash to conclude that they are equally nutritious?

3. What is the most nutritious part of the plant, and when? Illustrate.

4. For what does the plant need carbon?

5. How is carbon supplied to the air?

6. What gases make up the air?

7. Illustrate the fact that gases will mix, whatever their weight.

8. What fact, regarding carbon dioxide, does this explain?

9. What important share has carbon in the structure of plants?

10. Describe the two sets of cells in a leaf.

11. What happens in the "leaf-green" cells?

12. What two things are necessary to the supply of leaf-green?

13. How is the plant dependent upon the sun?

14. How do plants which have no leaf-green secure their food?

15. How do seeds and bulbs grow without leaf-green?

16. Describe the breathing of plants and of blossoms?

CHAPTER XIII

CLIMATE

The plant's whole life depends as we have seen, upon the sun, for without sunlight it cannot obtain carbon from the air and must starve. And this is equally true whether the plant manufactures its own food or whether it feeds upon what has been manufactured by others. The parasite sucks the juices of plants growing in the light, the fungus feeds upon dead vegetable matter which has grown in the light, the seedling lives at first upon food stored in the seed, by the leaves which waved in the sunlight, and so on.

But plants require of the sun something more than light; they must have some degree of heat as well—a very small degree in some cases, but this small degree is essential to bring them to maturity. Even those lowly plants which grow in snow and ice cannot dispense with some amount of heat, and though they contrive to exist in the lowest temperatures, they remain dormant during the winter, and only wake up when the summer sun begins to shine.

Many seeds will even begin to grow while it is freezing, though they cannot make much progress; and wheat has been known to germinate when actually upon ice, and to send out roots into it. Barley and oats will also send out roots with the thermometer down to freezing point, but they cannot develop seed-leaves without a few degrees of

warmth. Maize, as might be expected, requires more heat than any other corn, and will not start until the thermometer shows about fifteen and one-half degrees above freezing, and even then grows but slowly; and cucumber-seed shows no sign of life without still more heat.

But, though many seeds will make a start in cold weather, even in frost, it does not follow that they will do more than start; for a plant requires different degrees of light and heat at different times in its life. And if it does not receive enough at the important period when it has done growing, and is going to blossom, the chances are that it will bear no fruit. For fruit cannot do much towards feeding itself, and though it does take up carbon from the air, it is chiefly dependent for nourishment upon the leaves, the great food manufacturers. But in a cold summer, the leaves, instead of passing on their stock of food to the fruit, and themselves turning yellow, as they ought to do, seem to be quite thrown out of their calculations. They keep their food to themselves, and remain green and juicy, while the fruit is starved, and its development checked. In very bad cases, the plant puts out new shoots, and the crop never comes to perfection; for the heat which is quite sufficient for the growth of stems and leaves is not sufficient for the growth and ripening of the fruit.

If, on the other hand, the plant gets too much light and heat at an early stage in its life, it grows up and ripens its fruit too quickly, before it is properly developed; and this is what takes place when crops are sown too late in the year. In the ordinary course of nature, seed generally drops and sows itself as soon as it is ripe, and begins to grow forthwith. But it cannot go on growing.

Winter comes and checks it, and it is obliged to put off bearing fruit till the following summer. Plants grown in this, the natural way, are generally the stronger, if they manage to survive the winter. But they are exposed to more perils than when the seed is sown in spring, and of course they are much longer in coming to perfection.

Barley sown early in August and September, as soon as it is ripe, has been found to take two hundred, and two hundred and forty days, to come to perfection, which is just eight times as long as it often does in Egypt, where it is sown and ripened not only the same year, but quite early in the year.

Provided, however, the seed be not sown too late, the crop seems to be equally good whether the seed be sown in autumn or spring. Barley sown for experiment on the 21st of April came to perfection in eighty-eight days, that is, by the 18th of July; whereas that sown five weeks later ripened, indeed, in an equal number of days, but prematurely, before the grain was properly developed, because it had been over-stimulated—too much hurried, in fact, during the long, light, warm days of June.

Of all the influences by which the plant is surrounded, none affect it so powerfully, for good or evil, as light, temperature, and moisture, or, in one word, climate. Where the climate is favorable, the quality and quantity of the soil are of comparatively little importance, for the plant manages to make the very utmost of what it has. But where the climate is unfavorable, no soil, however good and abundant, can make up for it, though it may do something to lessen the evil consequences.

As we have already seen, the richest soil is unable to supply the place of water; while in Guiana, on the other

hand, where moisture is abundant, and the climate genial, groups of trees may be seen growing on a spur of the great sandstone mountains, wherever there is just sand enough to afford them a foothold. The sand is, of course, not mere sand, though it may look like it; but the soil is undeniably poor and shallow. Yet, helped by the climate, the trees thrive, as they could not possibly do without that help.

We are naturally accustomed to look upon the sun as the source of light and heat to our planet; but temperature does not depend solely upon the sun; for if it did, the same temperature would prevail all along the same parallel of latitude, which it certainly does not.

Rhine grapes, for instance, will not ripen in England; laurels and camellias flourish all the year round on the coast of Cornwall, while in the same latitude on the continent, only the hardiest trees can stand the winter. The vine can hardly flourish at the mouth of the Loire; yet it comes to perfection in Tokay, which lies a degree further to the north; and Astrakhan, in nearly the same latitude, has summer heat enough to ripen the southern fruits of Italy, and even of the Canary Islands, though its winters are so severe that no vine-stock would be able to live through them without being buried several feet deep in earth.

It is evident, therefore, that the climate of a country does not depend solely upon its position with regard to the equator. Indeed, the great characteristic of the equatorial climate is not so much its heat as its wonderful uniformity. Hot it is, of course, though not as hot as the plains of north India; but there is nothing to be called change of season, and there is seldom more than 16° or 17° of

difference between day and night. It is not often that the thermometer stands above 90° or 91° F. by day, or falls below 74° F. by night. And the temperature of the soil varies but little, too. Four or five feet below the surface it never varies at all, and remains constantly at 80° F., just about half-way between the temperature of night and day.

Where the temperature of the air varies more, there the temperature of the soil varies more also, and to a greater depth. At the equator, the sun affects only the upper four or five feet of the soil, the change between day and night being unfelt below this; but in England, the change between summer and winter is felt to a depth of fifty or sixty feet, probably; and below this the temperature remains steady at but a little above 40° F., which is about the mean temperature of the air in England, as 80° F. is that of the equatorial region—half-way between the two extreme points to which the thermometer rises and falls.

But this fact, that the depth at which the temperature of the soil remains always the same is so much greater in one case than in the other, has much influence upon the two climates; and for this reason: whenever a hot body is in contact with a cold, or cooler one, it at once gives up some of its heat to this other, and continues to do so until there is no difference between the two.

When, therefore, the sun warms the surface of the soil, the upper layer parts with some of its heat to the one below it, this to the next below, and so on, until that depth is reached where the temperature is always the same. At the equator, therefore, the heat, having only four or five feet of soil to travel through, soon raises the temperature of the whole mass equally, and then, as it cannot descend

any lower, it goes on adding to the heat of these upper layers, in which it accumulates. At night, when the sun is gone, the surface of the soil cools, and the reverse process begins; the heat stored during the day gradually passes up again to the surface, and from the surface into the air, so that both earth and air are kept at a more even temperature than would otherwise be the case.

But where, as in England, the sun has forty or fifty feet of cool earth to warm, naturally it is much longer about it, and the whole mass is consequently not warmed equally through till summer is at its height. Then, and not till then, the whole mass being warm, heat begins to be stored during the day in the upper layers, and is given up again, when the sun is down, to warm the air at night. Hence we have warm nights in July and August; and winter is less cold than it would otherwise be, thanks to the heat gradually given back by the great mass of earth.

But the heat given back to the air in this way would quickly escape, and benefit us little, were it not for the moisture in the air, which acts the part of a blanket, and keeps it near the earth. At the equator, the air is generally in a very moist condition all the year round; and this moisture, while serving the part of a blanket by night, acts as a veil or parasol by day, and prevents the sun's rays from being too scorching.

It is to the large quantity of moisture in the air that the region of the equator owes its very even temperature, therefore.

In the dry plains of north India the heat is scorching, much greater than at the equator, just for want of this veil; and the nights are often so cold that water is frozen,

because the heat received by day all escapes again through the clear air.

Everybody knows that a clear night is a cold night, while a misty or cloudy one is comparatively warm.

Among other circumstances, therefore, which greatly affect the climate of a country is its nearness to, or distance from, the ocean. For where constant evaporation is going on, on a large scale, as, of course, it is from the ocean, there the air must needs be loaded with moisture, with the consequences already mentioned: the nights are warmer, the days cooler, the winters less severe, the summers less scorching. In one word, the climate is more equable. Moreover, the ocean is warmer than the land, in winter and by night, while it is cooler in summer and by day; and this tends to further equalize the temperature.

If the neighborhood of the ocean tends to equalize climate, the neighborhood of any large expanse of dry soil does exactly the reverse, inasmuch as it dries the air.

If the Sahara were covered with water, the climate of the south of Europe would be many degrees less warm than it is; for the wind passing over it would be cooled instead of heated as it now is. It would also be moistened, and so more snow would fall in the Alps, and less would melt in the summer.

Then, again, there are the many ocean currents, hot and cold, which also influence climate to a considerable extent. Western Europe would be far colder than it is without the gulf stream, which brings about one hundred and sixty-six thousand cubic miles of hot water from the tropics to the North Atlantic in the course of each year. And this tremendous volume of steaming water, besides

warming the air, loads it with moisture; so that it is easy to understand why the winter climate of Ireland should be mild enough to allow of myrtles flourishing out of doors, and yet why the summer heat should not be sufficient to ripen certain fruits, owing to the thick veil of vapor which screens it from the sun.

Other local circumstances which affect climate in a greater or less degree are the presence of forests, rivers, lakes, mountains, which cannot now be dealt with in detail.

But plants are also affected in a minor degree by the color of the soils in which they grow.

Dark substances absorb more heat than light ones do; and snow will melt more quickly if a piece of black cloth be stretched above it, even though the two do not touch one another. In the Arctic regions the ice melts much faster wherever a small, dark brown plant, of the same family as the red snow, grows, because it attracts the heat. So, too, in some parts of Switzerland the peasants hasten the departure of the snow by strewing it with black powdered slate.

Dark soils are, therefore, usually warmer than light ones; and it is not an uncommon thing for gardeners to sprinkle a light colored soil with peat, charcoal, or vegetable mold to warm it, for these all act as sun-traps.

Melons are thus ripened, even in the coolest summers, at Freiberg, in Saxony, by means of a layer of coal-dust.

Grapes, too, in the Rhine district, ripen best where the ground is covered with fragments of black slate; and the vines are purposely kept near the ground, that they may have the full benefit of the heat which the slate absorbs by day and gives up again by night.

The difference in temperature between two substances, one of which is white and the other black, when both are equally exposed to the sun, is very remarkable. There will be as much as thirteen or fourteen degrees difference, for instance, in the temperatures of a piece of lamp-black and of a piece of magnesia.

But though color makes such an important difference in the power to absorb heat, it has no influence, apparently, upon the power to retain it. Indeed, though sand may absorb heat less quickly than a darker soil does, when once it is warm it remains warm longer than any other. The coarser it is, too, the less quickly it cools; and as coarse gravel, once thoroughly heated, retains some degree of heat even through the night, it is found useful to put it round grape-vines to keep them warm.

Great, and especially sudden, changes of temperature are particularly trying to most plants, though such as grow in deserts have become so accustomed to being scorched by day and frozen by night, as at least to manage to keep alive. But though an even temperature is in some ways most desirable, it does not by any means follow that all plants would thrive in the equatorial region. That region, as has been said, is characterized less by its great heat than by its remarkable uniformity of climate. It knows no change of seasons: it is always summer, always spring, and always autumn there, and many trees bear both flowers and fruit at the same time. But this constant activity, though it suits the trees and plants accustomed to it, is too much for our European fruit-trees and other plants; for these are in the habit of taking a winter sleep, and cannot get on without it. Transported to the equatorial region, they grow, indeed, freely enough, but too freely; for they

become evergreen, putting out fresh leaves all the year round, and are so exhausted for want of their customary rest that they are unable to ripen their fruit. This is the case even when they are taken to the cooler hill-country of Ceylon; and it is true even with regard to the vine, which, though a native of warm climates, still is not a tropical plant, and is accustomed to shed its leaves year by year. In the tropics, however, its leaves remain green, instead of giving up their stores to feed the fruit as they ought; the grapes fall off almost unformed, and the vine puts all its energy into growing leaves instead of fruit, not having strength for both. The one thing which it lacks is rest—the rest which in winter it is compelled to take.

It being, however, impossible to provide the vines with winter-cold in Ceylon, it was suggested that heat might perhaps be made to answer the purpose as well, and the experiment was tried of laying the roots bare for a time to the strongest sun. This had the effect of checking the flow of sap as effectually as frost could have done: the leaves dropped, the vines had their sleep, and awoke from it so refreshed and invigorated that they were able to bring their crop to maturity; and this plan has been adopted with success both in Ceylon and Bombay.

In those tropical regions, outside the equatorial belt, where there are periodical rainy seasons and long droughts, the latter answer all the purpose of winter, and are, indeed, winter, so far as vegetation is concerned, in spite of their intense heat. Trees and shrubs are as leafless in the desert of Nubia, for instance, before the rains set in, as if it were mid-winter, in spite of, or, rather, in consequence of, the terrible heat; and thus a time of rest is secured to them.

In the Far North we have a very different state of things.

Here, instead of its being necessary to secure that the plants shall have rest, the great thing is to provide that they shall make the utmost of the very short spring and summer which are all that fall to their lot. Their time of sleep lasts on an average ten months, and during the remaining two months they have everything to do, so that it is most necessary that they should make the most of their time. The days are, of course, very long, which is a help, while the nights are so light as to be hardly like night; and if Professor Nordenskjöld's observations be trustworthy, it seems that the plants do indeed turn every moment to account, by growing all night as well as all day.

But many of them do a great deal of growing in advance, so that as soon as the summer comes their blossoms and fruit, which need heat more than the leaves, may be ready at once to take advantage of it. These plants, that is to say, make very large, strong buds, which are packed full of leaves and blossoms, in a more or less undeveloped state, but with all their parts ready, before the winter sets in. Directly the growing time comes round again, therefore, they can burst out, and begin to gather food from the air at once, and the plant is able to blossom very early, thus insuring as much time as possible for the perfecting of the fruit.

Most of the plants ripen their fruit, but some few are not able to do so, except now and then, when the summer is hotter or longer than usual; and some which are annuals further south become perennials here, as they would not have time to grow from seed, and ripen seed, in one short season.

During the long winter many are of course protected by the snow; but there are wide surfaces here and there

left quite bare of covering, and yet even here plants manage to survive, some without any protection whatever, others because they are buried under a deep layer of dead leaves and stems. Whether in "deserts" of ice or "deserts" of sand, it would be equally difficult to find any spaces of large extent where vegetable life of some kind or other does not exist, at least during certain seasons of the year.

QUESTIONS FOR REVIEW

1. How important is climate in the life of a plant?
2. How do conditions vary in the same latitude?
3. What is the great characteristic of the climate of the equator.
4. Show how the temperature of air and soil affect each other in different latitudes.
5. What effect has the presence or absence of moisture? Illustrate.
6. What influence has the gulf stream?
7. Why are plants affected by the color of the soils in which they grow? Illustrate.
8. How do soils differ in the way in which they retain heat?
9. Why is the equatorial climate not best for all plants? Illustrate.
10. Compare the conditions of plants in Nubia and in the Far North.

CHAPTER XIV

BLOSSOM AND SEED

Plants, even the very humblest and lowliest, have, as we have seen, many requirements in the way of food of various kinds, water, air, light, and warmth. But having seen them duly provided with all these, we might fancy that now at last all their wants were satisfied, and that nothing more remained but for them to make the best of their opportunities and—grow.

But all depends upon what we consider to be the plant's object in life. For instance, we may be quite satisfied to grow orange-trees for their blossom merely, or maize for use as forage, and palms for the sake of their foliage, in climates where it is impossible for any one of them to ripen their fruit. And provided they throve and answered these purposes, our object would be attained.

But plants in the natural state grow to bear and ripen fruit. All the rest of their lives is merely a preparation for this one grand end. The roots draw food from the soil, and the leaves do the same from the air, all for the purpose of feeding and maturing the fruit—the one aim to which everything tends.

Of course, where man comes upon the scene it is quite another matter, as he can take cuttings of some, divide the roots of others, and fetch continual supplies of seed from the ends of the earth, if necessary. But the wild plant has not these resources to fall back upon, and if its

race is to continue, it must as a rule be able to perfect its seed, otherwise it will merely thrive for a time, longer or shorter, according as it is an annual or a perennial, and then it will perish without descendants.

But in very many cases the plant, like Mr. Belt's scarlet-runners already mentioned, is quite unable to perfect seed without the help of what we may call nature's under-gardeners. The plant does much for its offspring; it collects and stores food, it drains itself of its own life-juices for their benefit, but it cannot always do everything; and if these under-gardeners were banished from the earth, some plants would speedily vanish also.

Both blossoming and fruit-bearing are processes more or less exhausting to the plant, for neither flowers nor fruits do much, though they do something, towards feeding themselves. Annuals blossom and bear fruit once and then die entirely, roots and all, their leaves and stems being drained of nourishment by the end of the season. Others, perennials, die down, but their roots remain alive; and others again, merely shed their exhausted leaves, and grow fresh ones, for several or many seasons in succession. Others again, take more than one season to store food before they venture upon the expense of having blossoms at all; and others take many years to prepare for this great effort, and when it is at last accomplished, the great end of their lives, they die of mere exhaustion.

The food of blossom and fruit is, as has been said, very generally accumulated in the leaves and stems of the plant; but sometimes the root serves as the main storehouse. The turnip, for instance, like other biennials, spends the first year of its life in doing nothing but gather a store of food by means of its roots and its tuft of leaves.

It does not shoot up, and it makes no attempt to blossom; and as the farmer does not want turnip-blossom, and does want roots, he takes the latter while they are plump, and well filled with the food intended for the seed. If he waited till the next year he would see his turnip-plants shoot up rapidly and blossom; and very thriving they would look, no doubt; but all this time they would be sucking away at the roots, which would be losing their plumpness, and growing gradually hollower and more hollow, until, by the end of the second year, they would be reduced to nothing but fiber, and be quite useless.

We have spoken already of bulbous plants, such as crocuses, whose blossoms are nourished on the food previously stored for them in the bulb, by the leaves, which, in most cases, do the chief part of their work after the blossoms have faded. But in some instances, as in that of the colchicum, or meadow saffron, they come up and make their preparations in the spring, for the blossoms which do not appear till the autumn, long after the leaves have vanished. In these cases the food for the blossoms is stored in the bulbs; and if a tidy gardener unwarily cuts off the leaves before the bulb is properly stocked, he starves the blossoms.

But some plants take years to prepare food sufficient for the supreme effort of their lives.

The American aloe, for instance, which was supposed to blossom only once in a hundred years, though it does not wait quite so long as this, does actually wait five or six years in its own country, and from fifty to seventy in ours, before it attempts to send up a flower-spike. But when it does begin, it grows with such tremendous energy—at the rate of a foot a day even in our conser-

vatories—that one can well understand its need of a large store of food ready for immediate use, since it would be impossible for leaves and roots to collect, manufacture, and supply it as fast as it is wanted.

The aloe does not, however, always die of its effort, and may live to blossom again, some years later; but the Talipot palm, though it attains a great age, spends its whole life in accumulating food for its progeny; and having once blossomed, it is quite exhausted, and perishes.

Blossoming, then, is a serious matter for all plants, and not to be undertaken without due preparation. But it is a curious fact that the size of a plant's blossoms is often quite independent of the size of the plant itself. Many a forest-tree, for instance, bears flowers which are quite minute and insignificant; others, as some of the palms, bear spikes of blossom several feet in length and leaves in proportion. As a rule, however, trees have small leaves, small, dull blossoms, and small seeds for their size; but they bear all three in large numbers. A diminutive cactus, only a few inches high, on the other hand, may boast a glorious crimson flower, measuring two or three inches across; but then it has to be satisfied with one, or perhaps two. The beautiful night-flowering cactus attains some size, but it is a conservatory plant, not a tree, yet its blossoms measure half a foot across and it bears at times as many as twenty or thirty together.

The largest known blossom, however, is that of the extraordinary Rafflesia Arnoldi, a native of Java and Sumatra, which, much more truly than even the orchids, is "all blossom," for it has neither branches, leaves, nor roots. Of course, therefore, it must needs be a parasite, living by and sucking the life-juices from others; and it

produces a huge blossom, more than a yard across, mainly at the expense of the vine-like plant upon which it fixes itself.

It is not by any means a beautiful object, and its petals, which are thick and fleshy in texture as well as flesh-colored, have the smell of tainted beef. This monster takes several months to come to perfection, and then weighs about fifteen pounds; after which it begins, in a few days, to wither away.

An ordinary, complete, simple blossom, whether large or small, brightly colored or inconspicuous, consists of two sets of parts, or organ, an outer and an inner set. It is the function of the inner set to form the seed; and it is the function of the outer set to protect the inner from all injury, and also, in many cases, to attract the under-gardeners already referred to, whose good offices are required for the development of the seed.

The perfecting of the seed is the great thing to be accomplished; and those parts of the blossom which contribute to this object are placed in the center, as far out of harm's way as possible. If we examine, for instance, a common primrose, splitting it carefully upwards from the base of the flower, we shall see in the very center a hair-like stalk, with a knob at the upper end and a hollow swelling at the lower end. On splitting open this hollow part, we find that it contains a number of very minute grains, ovules, or little eggs, which, in the ordinary course of things, would be converted into seeds.

This central organ is the pistil, which consists of one or more bodies, named carpels, each with its hollow case, or ovary, below, and its stalk, or style, above; and these are either distinct one from another, or combined into one organ.

Outside the pistil stand the dust-spikes, or stamens—stalks bearing each a double sac, or anther, which is filled with the dust known as pollen. Pistil and stamens together form the inner and more important set of organs.

The outer set consists of a double envelope of leaves; the inner, or petals, more delicate in texture and more varied in color, forming the corolla; and the outer, or sepals, generally green, and forming the calyx. A perfect flower has all these parts, and some have double rows of each. Naturally our eye is attracted chiefly by the brightly colored part of a blossom, and we think little about the inner organs, which are often almost or quite hidden from our sight. But it is these inner organs which are really the only absolutely necessary parts of a blossom.

Many flowers have no calyx at all; some have no petals; but, provided they have stamens and pistil, they can still accomplish all that is necessary for the perfecting of their seed. Even pistil and stamens, however, may be, and often are, reduced in size and deprived of their stalks; but dust-cells there must be, and ovules, or grains to be developed into seeds, there must be if the plant is to bear seed at all.

Now all these organs, the inner set as well as the outer set, are really leaves—leaves whose appearance and duties in life have been altered. The calyx still looks more or less leaf-like usually, and it is not difficult to believe that the petals might be leaves, too, though more delicate and more daintily colored. But it is less easy to believe the same of stamens and pistil. Let us, however, look for them in any double blossom, and we shall find few if any, for they have been changed into petals. It is blossoms

with many stamens, such as the rose, ranunculus, anemone, or blossom with many florets, such as the daisy and dahlia, which are most commonly doubled by cultivation.

Nature does not grow many double flowers, for wild plants need seed, and double flowers produce little if any, seed being sacrificed to petals. Geraniums, which have only ten stamens, are among the plants, however, which have a tendency to increase the number of their petals; and among the single blossoms, one may often be seen with a petal or two more than the rest, or an extra small petal, which is half-way between a petal and a stamen. If the seed from this blossom were saved, some of the next generation of plants might have still more petals and still fewer stamens, and by carefully cultivating those having these peculiarities the gardener would at last obtain quite double blossoms. The orange day-lily, too, may sometimes be seen with one or more stamens enlarged into small petals and bearing an imperfect anther.

But we have now to see what it is which changes the little, immature grains in the hollow part of the pistil into seeds, capable of growing into independent plants. At first they are mere specks of matter to all appearance, and so they will remain unless they are brought into close contact with some of the dust contained in the sacs borne by the stamens. This is the special stimulant which they need to make them develop, and if it be kept from them they will simply shrivel and die, for nothing else will do instead.

This dust, or pollen, is contained in the anther, which is usually seated, or more often perched, and apparently very loosely perched, too, on the end of a stalk.

When the pollen is ripe, that is, ready for the use of the grains contained in the pistil, the chambers open and it is discharged. The pollen consists of hollow grains, varying very much in size and shape in different plants, though always alike in the same plant.

Pollen-grains are very beautiful objects when seen through the microscope, though they look like nothing but powdery dust to the naked eye. Their color is usually yellow or brown, but they are also red, green, blue, whitish, and even black; and though their general shape is round, or egg-shaped, they are of many other forms, wonderful in their great beauty and variety, and reminding one of microscopic shells.

Some pollen-grains, for instance, are covered with ridges or grooves; others, such as those of the hollyhock and aster, with spines; others again with hairs or thorns; those of the thistle are many-sided; of the fuchsia and evening primrose, triangular; of the chicory, six-sided; and if we could see, we should no doubt find a reason for every change of form and color, and discover that each was exactly adapted for its own special purpose.

Every pollen-grain is delicately coated with oil, probably as a protection against damp and wet, and all have upon them markings, like pores or slits, to some of which there are lid-like covers. Usually each grain consists of a single cell, though sometimes there are more, and the cells are filled with a liquid of a most nutritious kind, consisting partly of starch, partly of oil, and partly of some jelly-like nitrogenous compound.

It is pollen which is the flesh-forming food of the bee. It may live on honey, which is mainly sugar—not nitrogenous—during the winter, when it is doing no work, but

when it is taking long journeys to and fro, it needs something more nutritious to make up for the waste occasioned by so much muscular exercise, and it eats pollen, besides carrying it home to make bee-bread for the young grubs.

But our concern now is with the ovules, the possible seeds, lying inclosed in the ovary at the base of the pistil, while the pollen, which is to make seeds of them, is in the anther-sacs above, and as it would seem, out of and beyond their reach. The question is, how are the two to be brought together?

In describing the primrose, we mentioned that the top of the pistil ends in a knob; and this knob is a matter of great importance. It is called the stigma, and is of all sorts of different shapes in different flowers; sometimes merely a point, sometimes large and divided into lobes, sometimes feathery, as in most of the grasses; but whatever its shape, it has no covering of outer skin, as the stalk on which it is borne has, and it is more or less sticky, and often crowned with a bead of nectar. This bead is so large in some plants—as, for instance, the white lily—that it may be taken off; and if then a few grains of pollen from the anther be sprinkled upon it, we shall see that these will in about half an hour begin to swell and grow. Each grain will put forth a slender tube, very minute, of course; but in an hour or two it will have lengthened out, and the fluid contained in the pollen-grain may be seen passing down one side of the tube and up the other. Pollen-grains may also be grown in a solution of gum or sugar.

Now this is exactly what takes place when pollen falls upon the sticky stigma at the tip of the pistil, only that instead of growing in an objectless way, each grain sends

out its tube, or sometimes several tubes, in the most business-like manner, and with the most precise and definite aim. The object is to reach one of the ovules below, and to do this the tube, in many cases of more than hair-like fineness, pierces its way downwards through the stalk of the pistil, and makes straight for its aim with unerring exactness, entering one of the ovules by an opening in it which exists for this purpose.

Sometimes the tube may take months to reach the ovule, but more usually it accomplishes its purpose in a few days or hours. As soon as it has made its way into the ovule, it begins to pass into it the fluid contents of the pollen-grain, and the ovule begins to grow.

But the ovule does more than grow, it acquires a new character. At first it was a mere speck of matter, containing a germ-cell, indeed, but no germ, no rudimentary or embryo plantlet, such as one may see on splitting open a bean, pea, nut, or any other seed large enough for the purpose. The tube sent out by the pollen-grain enters the ovule, and the germ is developed and vivified by the liquid which passes down it. The seed, which before was unfertile, and could never have germinated and produced a plant, is now fertilized, made fruitful, and if allowed to come to maturity it will be capable of producing a plant like that by which it is borne.

It is quite possible in certain cases for ovules to grow and even to attain the size of seeds without being seeds, without having within them any living germ capable of independent life and growth. For each ovule is attached to the walls of its nursery, as one may see by looking at the peas in a pod, and is fed from the leaves. But unless it receives also the liquid contained in the pollen-

grain, it remains lifeless, and sooner or later shrivels and perishes.

The quantity of pollen prepared and needed for the ovules varies very greatly in different plants. The violet, for instance, produces about a hundred grains in each blossom, and the poppy more than three million and a half. Some ovules need only two or three grains of pollen to quicken them, and others several; some of the foreign orchids bear as many as seventy-four million seeds, and though they are very small, each seed requires the contents of about twenty grains of pollen to fertilize it; so that the quantity produced is necessarily very large. Moreover, a good deal more is required than the plant itself needs, as a considerable margin must be allowed for waste, some being blown away by the wind, some washed away by rain, and not a little consumed by bees and other insects.

Since the pistil with its sticky tip stands in the middle of the blossom all ready to catch and hold fast the pollen which is discharged by the surrounding dust-spikes, it would seem that there could be little difficulty about the matter, and that stamens and pistils might safely be left to manage it without help. But there are various obstacles in the way of this apparently simple arrangement.

In the first place, even though stamens and pistil be most conveniently placed, as it might seem, for the very purpose of giving and receiving pollen, it does not follow that they are so. For where is the use of their being within easy reach of one another if they are not both ready to act at the same time? And this is a thing which happens very frequently indeed. Sometimes the pistil is ready first; its tip is unfolded and sticky, and waiting for

pollen, before that of the surrounding stamens is ripe enough to burst from the anthers. But the pistil cannot go on waiting, and if pollen does not reach it at the right time, it is of no use its coming at all; the time is gone by, and the ovules are left to shrivel.

Often, too, the pollen is ripe first and all scattered before the pistil is ready for it; and here again the ovules must perish, unless pollen is brought from elsewhere. Even when pollen and pistil are ripe together, they may be out of one another's reach; for the pistil may be taller than the stamens, or the anthers may open outwards instead of inwards, and in neither case will the pollen be scattered on the pistil-tip, or be of any use to the ovules.

But there are more difficulties even than these. A perfect flower, as has been said, consists of a double set of outer and a double set of inner organs; but very many flowers are quite imperfect. One or both of the outer set of leaves may be altogether wanting, and one or other of the inner set may be also wanting; that is to say, some plants grow the pistil in one blossom and the stamens in another, but never both in the same blossom; and others go a step further than this, and grow their pistils and stamens not merely in different blossoms, but on different plants.

Those plants or blossoms which bear stamens only are of course barren, for they possess no ovules, as they possess no pistils; and those which bear pistils only are, or may be, fertile, since they possess ovules, which may become seeds provided pollen be brought to them from another blossom or plant, but not otherwise.

And then again, even when a plant bears perfect flowers with both pistils and stamens, it not unfrequently hap-

pens that pollen from their own blossom, or from another blossom on the same stalk, does not suit the ovules. Some which are fertilized by the pollen of their own blossom, close-fertilized, as it is called, do well, and the seed is plentiful; but in most cases it is poor, and even worthless. Sometimes the pollen from a blossom on the same stalk actually has the effect of poison, and when applied to the pistil-tip, causes it to shrivel and decay, and makes the petals drop; sometimes, again, it does neither good nor harm directly; it does not poison and it does not fertilize, but—which is equally injurious—it prevents any other pollen received afterwards from having any effect, so that in either case the ovules are equally sure to shrivel. Then, further, there are some plants, as, for instance, certain of the passion-flowers, whose ovules cannot be converted into seeds unless they receive pollen not merely from another plant of the same species, but from another plant of a different species—a passion-flower, but a different species of passion-flower.

Such, then, being some of the many arrangements by which it is made difficult or impossible for ovules to be fertilized by pollen from their own blossom, or from a blossom on the same stalk, one must conclude that there is some reason for them, and that seed is the better for being cross-fertilized—fertilized, that is, by pollen from another plant. And so, indeed, it proves; for if cross-fertilized and self-fertilized seeds be sown together, it generally happens that the former grow up so much the stronger as quite to overpower the rest.

As a rule, then, cross-fertilized seed produces much more vigorous plants than self-fertilized seed does. But still, as wild plants have to keep their own place in the

world, which they cannot do without offspring, it is better for them to have some seed, even poor seed, rather than none at all. And to insure this some plants manage to bear seed of both sorts; some fertilized by the pollen of its own blossom, some, if possible, by that brought from outside, so that if by any chance the latter should fail, they may still have something to fall back upon.

There is, for instance, that ubiquitous little plant, the common chickweed, weak-stemmed and fragile-looking, but not in the smallest danger of dying out, for it goes on sowing itself through many months of the year. Its first crop of seed is fertilized quite early in the spring, so early that the plant is left to itself, and has to make the best of its own pollen, which it does in the most thrifty way possible. The pollen is never scattered, so there is no waste, but while still in the anther-sacs, it sends out tubes in the direction of the pistil-tip, which it reaches without fail. This process takes place while the flowers are still only buds, so that pollen and tubes are carefully protected. The seed thus produced may be poor, much of it may even be useless, but at least what there is, is better than none; and later in the season, if circumstances are favorable, better seed will be produced by pollen brought from other plants.

Generally speaking, pollen-grains do not begin to swell until they actually touch the moist tip of the pistil, but in these early blossoms of the chickweed and some other plants, they never leave the anthers. The sweet violet, in like manner, bears some buds, smaller than the rest, which never open. These produce but a few grains of pollen, as there is no waste to be allowed for, and they send out long tubes without leaving the anthers.

The dog-violet, on the other hand, as it does not resort to this device, is quite seedless, unless pollen be brought to it; and other plants are much worse off, and can never set seed at all in this country, being unable to make use of their own pollen, and not finding here the messengers which, in their native land, bring them pollen from other plants. The greater periwinkle is one of these, and never has seed.

As has been mentioned, some blossoms have pistils so much longer than the stamens that it seems impossible for the pollen of the one to reach the tip of the former. This is the case with the colchicum, whose mauve-colored blossoms are much like those of the crocus. But when the pollen is ripe and the anthers have burst some of the dust is rubbed off upon the inside of the petals when the flower closes, as it does every night, several times in succession. Meanwhile the petals lengthen so much, that when the blossom closes for the last time, the first spots of pollen are brought up to a level with the tip of the pistil and are pressed against it, with the result that some of the grains adhere to the sticky surface and soon begin to grow, at the rate of something more than an inch in an hour.

In the case of the colchicum, the ovules are a very long way from the pistil-tip—as much as thirteen inches—but they are reached in about twelve hours. This takes place at latest at the beginning of November; but for some reason, perhaps because it needs warmth, the germ or embryo does not begin to form in the ovules until the following May.

The ovules of the American oak wait almost a year after the entrance of the pollen-tube before they begin to develop, and then take another year to ripen.

Why should the pollen-tube always grow with its end directly towards the very narrow opening by which it is to enter the ovule?

For the ovule is often far away—what, considering the size of the pollen-grain, may be called, without exaggeration, hundreds of miles away—while the door by which alone the tube can find entrance is the merest point. Indeed, the ovules themselves are often mere specks, and usually they are placed in what looks like a most inaccessible position, quite inclosed in the ovary. Often, too, there are hundreds, and even thousands of ovules in one ovary, each of which receives at least one pollen-tube, in some cases more.

Even when it has taken the first turn downwards in the right direction there is plenty of room—either on its way down the pistil stalk or when it reaches the ovary—for the tube to go astray. But instead of doing so it makes unerringly for its mark, and we can only conclude that some definite arrangements exist by which it is directed into, and kept in, the right way.

QUESTIONS FOR REVIEW

1. How are different classes of plants affected by the fruit-bearing process?
2. How do bulbous plants prepare for their blossoms?
3. What peculiarities has the American aloe?
4. What relation has the size of the blossom to the size of the plant?
5. Describe the peculiarities of the largest known blossom.
6. Describe the chief parts of a flower.
7. What are double blossoms?
8. Describe the pollen-grains.
9. How does the pollen reach the ovules?

10. What difficulties prevent many plants from being fertilized by their own stamens?

11. What fact is illustrated by the chickweed?

12. Describe the process of fertilization in the colchicum.

13. How are the wonderful processes of nature illustrated by the pollen-tube?

CHAPTER XV

THE GOLDEN RULE FOR FLOWERS

"Get fertilized! cross-fertilized if you can, self-fertilized if you must," that is nature's golden rule for flowers.

We have mentioned only a few of the curious and interesting arrangements by which the pollen is in very many cases prevented from coming in contact with the ovules of its own blossom; but enough has been said to show that this self-fertilization is generally discouraged, and made in many cases either difficult or altogether impossible.

We have now to see how cross-fertilization is provided for, and by what messengers pollen is conveyed from one blossom to another. These messengers are wind, insects of many kinds, birds, and even in some instances that most unlikely of gardeners, the ill-reputed snail.

Plants which depend upon the wind for bringing them the needful pollen have small, inconspicuous, and generally scentless blossoms; bright colors, sweet scents, and honey, being usually confined to those plants which need the services of birds and insects. The pistil-tips or stigmas of the former are also especially adapted for catching and holding the grains of pollen blown upon them, for they are either divided into plumes or feathers, or are plentifully beset with hairs. Grasses and sedges are chiefly wind-fertilized; and so, too, are many trees, such as the oak, beech, hazel, birch, elm, poplar, and pine, all

of which blossom early in the year, often before there are any leaves to interfere with the scattering of the pollen; and they mostly bear pollen and ovules in separate blossoms, some on the same tree, some on different trees.

The pollen-bearing, or staminate blossoms of these trees grow together in large numbers, in the form of tassels or catkins, which wither and drop when their pollen is scattered and their work done.

The catkins of the hazel contain more than a hundred blossoms, having no petals, but ten or twelve stamens each. The blossoms containing the ovules grow on the same tree, but they have no petals either, and are so small as almost to escape notice, for they look like nothing but small, scaly buds, with tiny crimson tufts on the top. These crimson tufts are the stigmas, outspread on purpose to catch the grains of pollen as they float by.

Pines, on the other hand, have not only no petals, but no pistil-stalks, and not even stigmas either; all that there is of the pistil being the ovary, which is scale-shaped and open, so that the pollen falls directly upon the ovules within it. As the ovules develop into seeds and grow, the scales that bear them grow also, and ripen into fir-cones.

Pollen which has to be carried by the wind is light, dry, and powdery, and is produced in very large quantities to allow for the unavoidable waste. It is carried far and wide, and the air is often filled with it, especially in the neighborhood of forests. Masses of pine-pollen are often found in America as much as three or four hundred miles away from any trees which could have produced it. Of course, where plants are dependent upon the wind for pollen, they are liable to have a great variety of it brought

to them; but this does not hurt them, for unless the right kind comes it simply has no effect whatever. But as it is of great importance to these plants not to miss any chance of the right pollen, and as the wind blows at all times, night and day, they never close, many being unable to do so from want of petals, so that they are always ready to receive it.

Among the trees which are fertilized at least in part by the wind are the palms, whose blossoms are small and dull-looking, and inclosed—thousands of them together—in a sheath, something like that of the arum. But some of the palms are very strongly scented, and when the sheath opens it is a center of attraction to a buzzing cloud of flies, small beetles, and other insects.

The date-palm bears ovules and pollen on separate trees; and when date-stones are planted it is found that instead of coming up half of one sort and half of the other, there are more of the fruit-bearing than of the unfruitful trees among them.

However, one pollen-bearing tree is well able to supply more than one ovule-bearing tree, and in their wild state the trees have no difficulty in obtaining all that they want. But when they are cultivated then they require help, though trees of both kinds grow in the same plantation. The fact is mentioned by many writers, from Pliny downwards, though without explanation; and in all the plantations part of the work consists in climbing the trees, first to collect pollen-bearing blossoms, and next to dust with them the little ovules, which are about as large as peas, and lie exposed in the center of the other blossoms, not inclosed in an ovary. If this is not done the date crop fails.

During Napoleon's campaigns in Egypt, the natives not having much leisure to attend to husbandry, the plantations about Cairo were neglected, and although the trees blossomed as usual the eatable dates were few.

In the East dates are such an important article of food, and the failure of the crop such a serious loss, that nations at war, and desirous of inflicting as much injury as possible upon one another, were in the habit of cutting down not all the palms indiscriminately, but those bearing pollen. On one occasion it is said that the Persians, fearing they might be injured in this way during a civil war, took the precaution of collecting the pollen from the trees, kept it in close vessels for nineteen years, and made successful use of it when peace was restored.

The Arabs are said always to keep some of the unopened sheaths containing pollen from year to year, in case of any failure in the blossoms.

It has been mentioned that pollen may often be borne long distances by the wind, and this has been exemplified in a remarkably interesting way by the case of a date-palm growing near Otranto. The palm is not a native of Italy, and though introduced, does not grow wild; and this specimen, being the only one of its kind in the neighborhood, was barren for years. But at last, one year, the young dates, instead of shriveling as usual, remained on the tree and grew to their proper size; and then it was found that a date-tree had flowered that same year for the first time at Brindisi, some forty odd miles away, and had borne pollen-blossoms. This pollen, therefore, had no doubt been carried by the wind to the tree at Otranto.

The case of another solitary date-tree, growing at Martinique, in the West Indies, is also interesting, though in

another way. For this tree bore eatable fruit without being fertilized, but though the dates might be eaten the stones would not grow, for the seeds were imperfect, and contained no germ.

The fruit of a plant, botanically speaking, is the ripened pistil, or rather that part of the pistil which contains the ovules. Sometimes, as in the case of the various kinds of corn, it is the ripened ovules, the seeds, which are the eatable part of the fruit, the ovary in which they are contained being a mere husk. In the various gourds, on the other hand, the ovary itself grows enormously and becomes fleshy. So, too, with apples, pears, peaches, nectarines, plums, and oranges, the swollen, ripened ovary containing the seed is the part best worth eating; and it has, therefore, been the gardeners' object to increase its size and improve its flavor. In the almond, the ovary remains a mere wooly skin without edible flesh; in the horse-chestnut it is a tough, thick, and prickly skin, equally uneatable; in the filbert and beech-nut it is a hard shell; and in the coconut it consists of fiber. Whether husk, shell, skin, flesh, or fiber, however, the whole ovary with the ripened ovules is properly the plant's fruit.

Generally speaking, the growth of the ovary, as well as of the ovules, depends upon pollen, and when the ovules are fertilized and begin to grow, the ovary begins to develop also, and not until then.

But it is not always so. Among the plants belonging to the order of Liliaceæ, which includes, besides lilies, the hyacinth, tulip, garlic, onion, and others, it is a common thing for the ovary to begin growing actively before the pollen-tubes have reached the ovules—before they are fertilized, therefore—though not before the tubes have

begun to penetrate downwards through the style. In these cases the ovary seems to be excited to growth by the pollen, though not in the usual way, and before the ovules are affected.

But in many plants the ovary, and even ovules, may be fully developed, altogether without pollen; though in this case the ovules do not become seeds any more than the "stones" of the Martinique date becomes seeds, and no plant can be raised from them.

Among the plants which ripen the ovary without the help of pollen are the Zante "currant" (really a small grape), many Maltese oranges, and some kinds of apple.

While some ovules are so independent as to be able to grow to the size of seeds, and even to assume the appearance of seeds, without being fertilized, there are, on the other hand, some—as, for instance, those of the orchids—which are not even formed until the pollen-tubes begin to grow towards the place where they should be. The pollen in these cases not only fertilizes them, but though still at a distance is the means of bringing them into being.

Of course, as pollen is so light, and easily blown about, many plants may at times be fertilized by the wind, besides those which are especially dependent upon it. Not many, one would suppose, are fertilized by water; yet there are one or two instances of this too curious to be passed over.

One of these is that of a small water-plant, nearly related to the duckweeds, which bears two blossoms inclosed together in a boat-shaped sheath, which floats upon the water. In the upper part of the sheath is a perfect pistil, with its ovary, short stalk, and stigma; in the lower part are the anthers containing pollen, which cannot by any possibility reach the stigma unless rain happens to fall

when it is ready. If it does, the sheath is gradually filled with water, and the pollen is floated up till it reaches the right place.

There is a still more curious arrangement in the case of the Vallisneria, which grows in the ditches in Italy, and is well known, though not in a flowering state, in fresh-water aquariums. This plant bears its pistillate and staminate blossoms on separate roots, which, however, seem to grow near one another. The pistillate, fruit-bearing blossom grows on a long, slender stalk twisted like a corkscrew, which uncurls and raises the bud just above the surface of the water when it is about to open. The barren, staminate, or pollen-bearing flowers, grow in great numbers on short, upright stalks under water; but just about the time when the other blossoms up above open and want their help, these buds loose themselves from their stalks and rise up like little air-bubbles, opening suddenly when they reach the surface. Here they float about on the water among the pistillate blossoms in such numbers that they often quite cover them, and by this means convey to them the necessary pollen. When this has been received, the corkscrew stalks, which are often as much as ten feet long, curl up as before, and the fertilized blossoms sink down again to ripen their fruit under water.

We must now, however, turn to the insects, among which bees have a foremost claim upon our attention, since none are more generally useful in carrying on the very important work of fertilization. Creeping insects are not, as a rule, useful visitors for flowers, as any grains of pollen which they may pick up by the way are liable to be brushed off again before they reach a blossom which might be benefited. But flying insects of all kinds, even to the

smallest flies and midges, when once dusted with pollen, are almost sure to convey a few grains to the next blossom upon which they alight.

Pollen is of vital importance to the plants themselves, besides serving as food to bees and other insects; but nectar, so far as appears, is of no use to the plant except as serving to attract useful visitors; and the same may be said of sweet scents and brightly colored petals. All these are, in fact, the one baits, the other signals, which the plant puts forth to make known to those who understand the language where pollen and nectar may be found.

"Good entertainment for bees and butterflies" is what the bright colors mean; and where, as is often the case, the nectar is concealed in some deep and safe recess where wet cannot injure it, many flowers have lines or dots upon some of their petals to point out where it may be found, and so save their visitors' time.

Many bees have a regular pollen-brush of thick hairs under their tails, with which they sweep up the grains; and even when their object is nectar, not pollen, they are almost sure to carry off a few grains by brushing against the anthers of the blossom they are visiting. For all bees are more or less covered with hairs, some of which, being webbed, are especially adapted for holding the pollen-grains, while the grains themselves cling all the better for the spines and hairs with which they are often beset.

Small insects are useful for fertilizing small flowers, but they may light upon a large flower, creep in, and even rob it of nectar, without coming into contact with the pollen at all, which is almost impossible in the case of the larger species of bees, with their hairy bodies. The bee, too, has another recommendation: it has to visit many

flowers before its crop is filled with nectar, and both hive-bees and humble-bees, especially the latter, seem generally, though not invariably, to confine their visits to one kind of flower on each journey—a very important matter, as pollen of different sorts would in most cases be useless.

Of course the bee may, and does, convey pollen from blossom to blossom of the same plant, which may produce self-fertilization of a sort; but when it has visited all the blossoms on one plant, and flies off to another, the first blossoms visited there must needs stand a good chance of receiving pollen from the last of the former.

That the work thus done by bees is in many cases absolutely indispensable there is ample proof, though we may not always recognize it.

The bean-crop failed in Nicaragua just for lack of the right sort of bee; and often when the young gooseberries, or what should be gooseberries, wither and drop in early spring, instead of swelling as they ought to do, it is not so much because they have been nipped by the frost as that the frost has kept the bees at home. For the pollen and pistils of the gooseberry-blossoms ripen at different times, so that the one must be brought to the other if the ovules are to be fertilized; and if this is not done, neither they nor the berry containing them can grow to their proper size.

One year there was a remarkable scarcity of holly-berries in different parts of the country, which some people thought was accounted for by the cold weather in the early part of the year. But the holly is a very hardy shrub, and grows in Norway as far north as 62°, so that it was not likely to have suffered from an English spring. On the other hand, bees were remarkably rare that season;

and as the holly grows its stamens and pistils mostly on different plants, the dearth of berries was doubtless owing to the absence of bees.

For though holly-bloom are insignificant, they are fertilized chiefly by bees, and not by wind, pollen having been observed by Mr. Darwin on many pistil-tips, which must have been brought from a tree sixty yards away, and could not have been conveyed by the wind, since it was blowing in the wrong direction.

The year that the holly-berries failed, the crop of clover-seed failed also in some parts, and no doubt from the same cause. For though some clovers manage to fertilize themselves more or less, there is a very marked difference in the quantity of seed borne by the plants, according as they are kept covered, and out of the way of insects, or not.

A hundred heads of common red clover bear about two thousand seven hundred and twenty seeds among them; but a hundred heads covered with a net on one occasion, to keep off the bees, had not one single seed. This common red clover has a tube, too long to be sucked by the hive-bee until it has been mown, when the second crop of blossoms are said to be rather smaller, and its first crop is dependent on the humble-bee. A very slight difference in length makes just all the difference as to the species of bee which is able to extract nectar from the blossom. The brilliant crimson clover is frequented by the hive-bee, its tube being shorter than that of the common red kind.

Strawberry plants are altogether dependent upon bees for the perfecting of their fruit, even where pollen and ovules are produced in the same blossoms. In one species of strawberry, the true hautbois, they are borne

by different plants; and in the great market-gardens of America, where this is grown, it is usual to plant one row of barren plants to every three rows of fertile ones, leaving the bees to do the rest.

A great deal has to be done to insure the thorough fertilization of the strawberry-ovules, for there are from a hundred to three hundred in each fertile blossom, and there are an equal number of pistils. The pistils are set upon a cone-shaped receptacle in the center of the blossom; each one contains in its ovary a single ovule, and the ovary and ovule ripening together, develop into a tiny nut, which is the fruit properly speaking.

As the nuts grow, the conical receptacle on which they are set grows too, and becomes soft, fleshy, and sweet, forming what we erroneously call the "berry."

But if the "berry" is to grow properly, every one of the pistils must receive a few grains of pollen, and if any are left out, the ovules belonging to them do not grow, and the part of the receptacle which surrounds them does not grow either, but remains hard. The hard spots sometimes found in strawberries, with a number of little "seeds" crowded together, are due simply to the fact that the ovules have not been fertilized, and have withered instead of growing.

So, too, with the raspberry. Each one of the sixty or seventy little fruits composing the "berry" depends upon pollen for the power of developing not only its seed, but also the sweet, juicy envelope surrounding each seed. Towards the end of the season these often fail and wither, because the bees are either dying off, or do not care to come out unless the weather is tempting.

Then, again, with apples; one may often see an apple

which is deformed, having grown on one side; and the reason here, too, is similar.

The calyx of the apple-blossom is a tube which spreads out at the top into five leaf-like divisions. Inside the tube, and joined to it, are the ovaries, which together form the horny core. When the stigmas are all properly dusted with pollen, each ovary, with its two pips, begins to grow; but if nothing else grew, there would be no apple, only a horny seed-vessel, the only eatable part of which would be the seeds. But the calyx inclosing the core grows too, and so does the top of the stalk from which it springs; and it is these which together form the apple.

If, however, one of the stigmas be by chance left without pollen, then the ovary belonging to it, with its two pips and the part of the calyx next to it, does not grow, and the apple is misshapen.

There is a French apple called the S. Valery apple, which is remarkable for having a double calyx and a double core, with ten divisions, but no petals, and only imperfect stamens, which produce no pollen. This has to come, therefore, from different varieties, and it is a regular custom for the girls of S. Valery to go to the orchards in the spring, taking pollen from various other apple-trees, to, as they say, "make their apples." Each marks with ribbons her own fruit, and the different pollen produces apples of different flavor, color, and size, according to the variety of apple from which the pollen has been taken.

Occasionally one hears of an apple-tree which indulges in the freak of bearing fruit, some of which is of the ordinary shape, and some pear-shaped, both sorts growing on the same twigs. In this case one must suppose that the

bees have been less particular than usual, and have dusted the pistil-tips with pear-pollen. So, too, an orange-blossom crossed with pollen from a lemon will bear fruit which is partly orange, partly lemon, with peel partly of the one, partly of the other.

Among the many plants visited by bees, large or small, are the foxglove, mallow, and campanula, all of which, though they grow pistils and stamens together, ripen them at different times. Any one not knowing this, and examining a campanula-blossom, would be puzzled to know what could have become of the stamens, for when the flower opens they have generally vanished; the pollen is there still, however, having been discharged upon the stalk of the pistil before the bud opened, after which the stamens shriveled away. It is caught and held by the hairs with which the stalk of the pistil is clothed, apparently for the very purpose of holding it until the bees come and carry it off. When the pollen is gone, the tip of the pistil unfolds from three to five spreading branches which no pollen can reach while they remain folded; and then, back come the bees, this time in search of nectar, but bringing with them grains of pollen in abundance from other flowers.

Some pistils, as has been said, are actually poisoned, and others unaffected by the pollen of their own surrounding stamens. But there are others which carry their likes and dislikes a point further still, and require pollen not merely from the blossoms of another plant, but from blossoms whose stamens grow at exactly the right height; and if it comes from stamens too short or too long they can make little if any use of it.

There is, for instance, the great purple loosestrife,

whose tall, handsome spikes of blossom light up the river banks. The pistils and stamens of this plant are of three different sizes, but they correspond exactly in height, long pistils with long stamens, short with short, and middle-sized with middle-sized. The long stamens have emerald-green pollen, the others yellow; and the grains vary in size with the length of the stamens, the longer the stamens the larger the grains; for the larger grains are destined for the longer pistils, and have, of course, to send out longer tubes in order to reach the ovules.

A bee entering a blossom in search of honey is dusted with pollen on different parts of its body, according to the height of the stamens, and when it flies off to the blossoms of another plant, if the spots of dust come in contact with pistil-tips of the proper height, they may be caught and kept.

The red Oxalis is another of the plants having pistils and stamens of three sizes, and a large field in Brazil containing many acres of this plant yielded not a single seed, because, though pollen and insects were both plentiful, all the plants chanced to be of the same "form," as it is called—all had long pistils and short stamens, or *vice versâ*, and the pollen was of no use. Other plants possess similar peculiarities, but we will mention one which all can examine for themselves, the common yellow primrose.

The blossom of the primrose is a long tube flattened out at the top into five divisions. If we look at a bunch of primroses gathered from different plants, we see at once that all are not alike. In some the pistil, with a knob like a pin's head, stands up just out of the tube; in others no pistil is visible, but in its place, just at the same

height, are five stamens standing up like teeth, the stalks being so very short that they are almost all anther. In spite of their shortness, however, the stamens are on a level with the long pistil of the other blossom, for they are attached to the flower-tube, and for the long pistil their pollen is intended. The pollen-grains of the stamens which grow with the long pistil—but out of sight, half-way down the tube—are intended for the short pistil, whose knob is just at their own level, and accordingly, they are smaller.

All flowers which vary in this way, all which are distinguished by color, scent, size, or irregularity of shape, are mainly indebted for fertilization to insects. This is the case with all bell-shaped and tubular flowers, also with the snap-dragon and foxgloves, and with the dead nettles, lavender, thyme, and all blossoms of similar shape to these, besides many others. In some the shapes of the blossom and of the insect by which it is fertilized are as beautifully and "exactly fitted one to the other as the lock is to the key," and in others there are endless different devices for securing, that the visitor shall not depart without doing some service in return for the pollen or nectar which it has consumed or carried off.

In the common stinging nettle the four stamens lie folded down flat until they are touched, when they spring suddenly up and scatter their pollen; a needle inserted in the throat of the common purple lucerne causes two stamens instantly to start up like a jack-in-the-box, the anthers at the same time exploding and discharging their dust. A similar explosion takes place in the flowers of the whin, and in many others. In one plant the anthers act like a pair of bellows, and on being touched blow their

dust out upon the insect; in another—the Kalmia, or American mountain-laurel—the stamens rise up from the petals on which they usually lie flat, and close round the insect, clasping it and impressing their pollen upon its body.

But the various arrangements are so numerous that it is impossible to do more here than give the merest outline sketch of them, and for fuller particulars the reader must be referred elsewhere.

We have confined our attention hitherto chiefly to bees, because they are the most generally useful of insects, and few flowers seem to come amiss to them if only they can reach the nectar. But there are just a few flowers which they actually avoid. Bees of all kinds, for instance, shun the crown-imperial, though it blossoms in March and April, when bee food is not plentiful. Gilbert White noticed a small bird like a white-throat running up the stems of this plant and plunging its head into the bells in search of nectar, so it may be that it is fertilized in this way, for it certainly sets seed.

Other flowers disliked by bees are the passion-flower and dahlia—which seem to stupefy and often kill them, and above all, the oleander, whose nectar is fatal. A traveler in Hungary and Dalmatia, where the oleander abounds, could not remember ever to have seen bee, moth, or butterfly visiting the blossoms. And yet their bright rose-colored petals seem to say, in the language of flowers, that they need the help of insects, and those, too, of a high order; for colors have much meaning in the flower language, and show to some considerable extent what kind of insects are wanted for the blossoms which display them.

White, for instance, serves to attract insects of all

sorts; but bright yellow seems to be especially favored by beetles, and blue by bees, though they do not, of course, confine themselves to flowers of this or any color. What a flower lacks in color may often be more than made up for by its sweet scent and abounding nectar. The dull pink sedum, for instance, which blossoms in the autumn, attracts a swarm of humble-bees and butterflies; though, as its flowers are flat and tubeless, the nectar is open to all comers, and bees are not necessary to it.

Yellow is said to attract insects of the lowliest kind; white, those a little higher in the scale; and pink, red, lilac, purple, blue, rank higher and higher as to the insects which they attract, that very superior insect, the bee, being, as already said, especially pleased with blue.

It is the fashion at present to say that the bright colors and sweet scents of flowers exist solely for the plant's own benefit, as the means of drawing to it the insects which carry pollen from one blossom to another. Nevertheless, man is gratified abundantly; and if this theory be correct, he may at least congratulate himself on the fact that he and the insect-world are of one mind as to what is agreeable and attractive.

But are he and they altogether of one mind? The butterfly will hover about a lavender-bush, attracted by the perfume, and so far man shares its taste; but it will also go and drink daintily at a drain, and for anything that appears to the contrary, an ill scent may be as pleasant to it as a sweet one.

Ill-smelling flowers, as well as sweet ones, have their admirers, and are certainly not especially avoided by insects; and flies will regale themselves upon honey or filth with apparently equal satisfaction. Ill-smelling

flowers are, however, comparatively very few; and as their colors are generally deep yellow, orange, brown-red, or brown, we may conclude that they are not frequented by such high-class insects as bees.

QUESTIONS FOR REVIEW

1. What classes of plants are wind fertilized?
2. What usually are the characteristics of their blossoms? Illustrate.
3. Give some peculiarities of the palm.
4. What is the true fruit of a plant? Is it always edible. Give illustrations.
5. Does the ovary ever develop without pollen? Illustrate.
6. Give instances of the use of water in fertilization.
7. Describe the way in which flowers are fertilized by insects.
8. What parts of the strawberry and of the apple form what we call the fruit?
9. What peculiarity has the campanula-blossom?
10. Describe the blossom of the primrose. What fact does it illustrate?
11. Describe the effects of colors in attracting different insects.

CHAPTER XVI

GUESTS, WELCOME AND UNWELCOME

Bees do more, on the whole, for the fertilization of flowers than any other insects; but though plentiful throughout the plains of Europe, they become fewer and fewer as the traveler ascends the Alps; and in the Tyrol, at a height of from six thousand to nine thousand feet, he may see hardly so much as a bee a day, and that of the "humble" species only.

There is, it is true, the Ligurian, or yellow Alp-bee, which is a mountain insect, and thrives in some of the southern cantons of Switzerland up to a height of four thousand five hundred feet; but still, the higher one goes the fewer bees there are of any kind; and though there are many beetles and flies, and very many moths and butterflies, there are, on the whole, fewer insects of all kinds in these higher regions; and in the highest, bees are almost entirely absent.

Yet the flowers of the high Alps are so intensely bright in color that it is pretty certain they must be visited by insects of some sort; and besides being of such vivid colors, the flowers here are made still more striking by being massed together in large beds, instead of being scattered here and there. For the fewer the insects, the more needful it is to economize their time and labor, and to avoid the risk, which solitary plants would run, of being overlooked altogether. Here, as elsewhere, "union is

strength"; and the butterfly must be blind indeed which could fail to notice these masses of brilliant color.

For the chief flower-visitors in these Alpine regions are moths and butterflies, together with flies and beetles; and it is curious to see how flowers which are visited by bees in the plains and lower mountain-regions are modified to suit moths or butterflies when they come up higher.

Of the many orchids, for instance, which grow in the plains, all but very few—four or five, perhaps—are visited by bees; but in the Alps, out of five species, all but one or two are dependent upon butterflies or moths.

Flowers change in color when they migrate to these higher regions, on purpose to attract more notice. Our pale yellow primrose is fertilized almost entirely by moths. but it might be overlooked among the bright flowers of the Alps if it did not dress more gayly there, so it wears brilliant pink and magenta. The wild pinks also, which straggle about here and there in the lowlands, sure not to escape notice among the many visitors constantly flitting to and fro, here take the precaution of growing larger blossoms, besides massing themselves together in such a way as to catch the eye of any wandering insect.

Large masses, large blossoms, brilliant colors—these are the means by which the fewer insects of the high Alps are guided without loss of time to the place where they are wanted; and flowers which might never be found out if they grew separately are insured against neglect by thus growing in company.

But many and beautiful as are the moths and butterflies of the mountains, one must go to the tropics to see them in their full glory of numbers, size, and coloring.

Of all parts of the world, South America is richest in

butterflies, and the richest part of South America is the region of the Amazons; where, also, the broad belt of forest which surrounds the land-surface of the earth almost continuously at the equator is denser than anywhere else, and swarms with insects of many kinds.

There are some twelve hundred species of butterflies in this region; but these gay insects do not care for the solemn depths of the forest, where they find little or no entertainment, and they are chiefly to be seen in the more or less open paths, where there is more light, and where, consequently, more flowers are to be found.

Here large blue butterflies, and many others, fly along for miles, and always return if driven into the forest. For this is gloomy and even musty, like a cavern; the damp ground is not covered by herbage, there is little beauty or brilliancy of coloring in the trees, and flowers are rare.

The fact is that, according to the German proverb, "one cannot see the forest for the trees." They are so crowded together, and they run up to such a height, that there is little to be seen but trunks, canopied by a mass of foliage so dark and dense that the sun is quite powerless to penetrate it.

Many trees never blossom until they are a hundred feet high, and it is only when a shower of bright petals falls from above that there is any sign of what is going on overhead, or of the beauty, displayed to insects only, outside the dark canopy. Beneath it the world is dank, dull, gloomy, unrelieved by a ray of light; but what a different world it is above! Here the sun is in full blaze, and bees in swarms are humming cheerily over the magnificent banquet of flowers spread for them.

Bees do not like gloom, or even the checkered shade

which contents the butterflies, and they would have missed the feast if the flowers had grown down below.

It is by the roadside, on the margin of the forest, in the paths, and along the river-banks that the real beauty of tropical vegetation is to be seen; for here are bushes, shrubs, trees of every height adorned with festoons of creepers, and brilliant with bright flowers and gorgeous butterflies.

Even here, however, there is nothing to surpass such masses of glorious color as are to be seen on our heathery moors or gorse-covered commons; and though tropical blossoms are undoubtedly splendid, they are not as common as one is apt to fancy, and they generally last but a short time, beginning to fall almost at once.

Bees abound in this region, but they keep in the sun, among the blossoms borne high up overhead; and the butterflies float lazily along the paths which are checkered with light and shade, but they keep for the most part near the ground. If the smaller trees, therefore, followed the example of the giants of the forest, and bore their blossoms on their tops, they would be in danger of missing both classes of visitors. The bees would know nothing about them down in the shade, and the butterflies would not rise high enough to find them.

Under these circumstances, therefore, many trees, such as the custard-apple, bear their blossom on the trunks or larger branches, where moths and butterflies can find them. The cacao is another which does so, and when the large yellow fruit is ripe, the trunks of some of the smaller trees are hardly to be seen, so thickly does it cover them.

But much as these insects do, both in the tropics and in the mountains, it must not be supposed that their ser-

vices could be dispensed with even in temperate latitudes and in the plains. Quite the contrary. Most of the European orchids are fertilized by bees, but just a few species cannot get on without the help of moths. There is a large sphinx-moth which carries pollen to and from one species of orchid in a very curious way—on its eyes. The pollen of this flower grows in two masses, each perched upon a stalk which passes through its center, and to which the grains are united. At the base of the stalks are tiny, button-shaped discs, one on each side of the stigma, face to face. When the moth presses its head into the center of the flower, the discs come into contact with its eyes, and being very sticky, they adhere so firmly that the whole thing is dragged out—stalk, pollen, and all. A very strange object one of these moths is when it is thus adorned, for the stalks, with their lumps of pollen at the end, at first stand out straight, like horns in the wrong place. In a minute or so, however, they contract and bend down, and then the pollen is in exactly the right position to be caught and held by the stigma of the next blossom of the same species, which the insect must, one would imagine, be in haste to enter if it knows how it may get rid of its undesirable appendages.

Orchid-blossoms remain in full beauty a long time, whether cut or not, as long as they are not fertilized; but when insects are allowed to get at them, they fade rapidly and go to seed.

Among the flowers specially attractive to moths in Europe are the valerian, petunia, phlox, hop, nettle, pink, ivy, clematis, pansy, jessamine, and honeysuckle, the last being frequented, according to Gilbert White, by a large sphinx-moth, which appears after dusk, and feeds, like

the humming-bird, on the wing, scarcely ever settling, and making a humming noise with its wings.

The jessamine is probably fertilized by the hawk-moth, which hovers in like manner; but jessamine-seed is rare in England, for hawk-moths are rare, too. But the want of hawk-moths may not be the sole reason for the scarcity of seed. The humble-bees are also in some measure to blame, for they come to the blossoms in search of nectar, and finding no perch upon which they can stand to suck in the proper way—the only way to benefit the flower—they get what they want by gnawing through the tube of the corolla, which soon drops in consequence.

Flowers which open at night are of course especially dependent upon night-flying moths; and as colors would not be seen, they are generally white or pale yellow, and have no lines to show where the nectar is, for these also would not be visible; but they are often so sweet as to be scented from afar. The large white bindweed, though it opens by day, remains open at night, when the moon shines, but not otherwise, to receive the visits of moths.

Wherever, in any part of the world, there is a dearth of bright-colored flowers, there, as a rule, is a scarcity of insects, and *vice versâ*, for where insects are wanting, there the flowers fertilized by them cannot of course flourish.

The scarcity of both these is very conspicuous in the Galapagos Islands, situated on the equator, some seven hundred miles west of South America. In Juan Fernandez also, which lies about four hundred miles off Chili, ferns form the larger part of the vegetation, as they do in most of the South Sea Islands. But there is no such

total absence of showy blossoms in Juan Fernandez as in the Galapagos. One shrub which flourishes there bears snowy blossoms, like those of the magnolia; another, also plentiful, has dark blue flowers; and besides these, there are large patches of a white, lily-like bulb, and there are two conspicuous yellow flowers as well.

Yet Juan Fernandez is poor in insects. It has but one butterfly, and that is rare; there are only four species of moths, and no bees at all, but some which are very minute, and of no more use to large blossoms than the flies, of which there are twenty species.

But the poverty of the insect-life is made up for by the presence of humming-birds, which are so abundant that there are one or two in every shrub; and these when killed are usually found with the front of their heads covered with pollen.

The group of honey-eating birds is so immense, both in the islands of the Pacific, Australia, America—North and South—the Moluccas, etc., that there can be no doubt as to the large share they take in conveying pollen from one flower to another.

The ruby-throated humming-bird frequents lilacs, phloxes, portulaccas, morningglories, roses, honeysuckles, snap-dragons, fuchsias, and many other flowers; and in dry weather, before the spring begins, it will even enter greenhouses and suck the fuchsias there, which it does more rapidly than the honey-bee.

The Portuguese name for the humming-bird is Beija Flor, "Kiss-flower"; but the little creature is not so ethereal in its habits as its appearance and poetical name have led people to suppose. It does "kiss" the flowers, but with a view to something more substantial than nectar

merely, though that may be all very well as an addition to its food.

Many a humming-bird has been starved to death in captivity, owing to the mistaken notion that honey, or sugar-and-water, was all that it needed; whereas these living, flashing jewels possess tongues which are exactly adapted for picking up insects; and insects are their principal food, though they take nectar as well.

The humming-bird's tongue is long, and can be stretched out far beyond its bill; it is very flexible, and being cleft in two it can be opened and shut at will, "like a delicate, pliable pair of forceps."

The humming-bird is, indeed, nearly related to the swift, and its chief diet consists of the small insects, which are seldom wanting in the long-throated blossoms of the tropics. The sheaths of the arums and their kindred are generally full of insects, too; so are those of the palms, and the "pitchers" with which many plants are furnished likewise afford insects in abundance.

Whether the birds go for nectar or for insects, it is all the same so far as the plant is concerned, for in neither case can they help coming in contact with the stamens and getting their heads and beaks dusted with pollen.

Bees, butterflies, moths, birds—these are the most conspicuous of the "under-gardeners" to whom is intrusted the important work of fertilization; but there are others equally useful in their way, though their sphere of operations is less extensive. Even the wasps do something, for in the absence of fruit they suck flowers, as Gilbert White remarked, especially those of the ivy and small umbelliferous flowers; they are especially attracted by the red and yellow blossoms of the "poker-plant"

(Tritoma), which blossoms in the late summer, and may be seen creeping quite into the tubes; and they are also said to fertilize the dahlia, which is shunned by bees.

"Where the bee sucks honey the wasp sucks poison," is a common saying, and as devoid of foundation as such sayings often are. It is a libel on the wasp, and too flattering for the bee; for if the bee does suck and store honey, which last the wasp does not pretend to do, it also secretes poison, and its sting is generally considered much the worse of the two.

To small, flat flowers, whose nectar lies so near the surface as to require little probing for, beetles and small flies are almost as useful as bees, and may be seen in crowds on such little blossoms as those of the wild carrot, and others of the same family which grow together in flat heads or umbels. Even the water-side midges do their part among the small flowers of the river banks.

All sorts of little flies, gnats, and midges are attracted also to the arums, some by the prospect of pollen and nectar, others, as the carrion-flies, by the flesh-like appearance and smell of many foreign species, on which they even lay their eggs, supposing that their grubs will be well fed; another illustration of what was said before, that if they existed solely for the purpose of attracting insects, all flower scents might just as well be what human beings consider disagreeable.

The arrangements of the arum family are so curious as to be worth a little special attention. We most of us know the so-called "arum-lily," with its white flower with the golden scepter. The flowers of the arum are contained in a sheath, properly called a spathe, which is snowy white in the "arum-lily" and greenish in the wild

one. The real blossoms are clustered round the scepter, or spadix, which is golden in the one, and purplish, or brown, in the other.

In some of the southern and foreign arums the lower part of the sheath, which is enlarged and contains the blossoms, is shut off by a ring of longish hairs which point downwards and allow the visitors to enter easily, but effectually prevent their coming out again until they have done what is wanted of them. The lower part of the spadix generally bears the flowers with pistils, those with stamens being arranged in a ring a little above. The lower blossoms are ready first, and to them the insects, or some of them, bring pollen from other flowers of the same species. But it is not enough for them to bring pollen, they must also carry some away, and for this purpose they must be kept until the anthers burst.

Meanwhile their prison is made very comfortable for them; it is pleasantly scented—we are not speaking now of the fleshy species—it is also warmed and provided with nectar. When the anthers burst, pollen is added to the feast, and some of the captives devour it so greedily as to be quite intoxicated. Enough, however, remains adhering to their legs and bodies to make them acceptable visitors elsewhere, and as soon as the pollen is shed, and there is no further reason for keeping them, the hairs which prevented their escape wither and die, and they are free to depart—generally, but not always. The hairy arum of the South is said to show her gratitude for the services rendered to her by her visitors, carrion-flies, in a remarkable manner. She catches and devours many, digesting them by means of the sticky hairs which cover the inside of the sheath.

Most of the arums of the temperate zones blossom early in the year, when the nights are still chilly enough to make the prospect of a warm lodging attractive.

Blossoms breathe more rapidly than leaves, and are always therefore a little the warmer. Buds just opening breathe so fast, if they are large, like those of a cucumber, that when they are isolated under a glass containing a tiny thermometer, the mercury may be seen to rise sometimes nearly two degrees.

Many blossoms heat so much more than this, however, that the difference may be felt as well as seen. This is the case with the arums, whose so-called blossom is really an assemblage of many blossoms. In the common wild arum, "lords and ladies," the temperature rises several degrees, but in the heart-leaved arum of the Isle of Bourbon the temperature of the sceptre, or spadix, has been known to rise to 95° F., and nearly 102° F., and that, too, when the temperature of the air was only 59° F.

But the common Italian arum outdoes even its tropical cousin, and its spadix becomes hotter than a hot bath, its temperature being nearly 110° F.

Arums are especially marsh-plants, and though one does not naturally associate the idea of warmth with such cold creatures as snails, it seems that it is these which are chiefly attracted to the arums of south Europe, and no doubt, of other parts of the world.

One of the foreign arums grown in hot-houses for the sake of their handsome foliage was observed one day at noon to begin to blossom and grow warm at the same time, its temperature rising beyond 100° F. Suddenly it gave out a strong, fragrant scent, between that of cinnamon and musk, which filled the whole house, and would no doubt

have been a well-understood signal in its own country, telling the small marsh-snails that their night quarters were ready. These would climb the stalk and find entrance by a narrow opening at the base of the sheath, which would soon after close upon them. Twenty-four hours later the scent and warmth have much diminished, but then the anthers open and drop down their pollen, not in separate grains, but in chains or tassels of grains adhering together, as much as an inch long, and far too bulky therefore to be carried away by insects. On coming in contact with the moist bodies of the snails, however, the chains separate into grains, which adhere and are borne away when the guests move on.

And they are obliged to move on soon after the pollen has fallen or else they would be suffocated; for the blossoms have been breathing vigorously in a confined space, and so much carbon has been burned, and so much carbon dioxide produced, that the bulb of the sheath is completely filled with it, and a glowing match held within is extinguished. Such visitors as stay too long are therefore safely suffocated, and thus prevented from eating the young fruit, which they would otherwise do without fail.

The prudent snails, however, having enjoyed their warm bed and nectar, do not outstay their welcome; but when these passing pleasures have come to an end, they linger no longer, make the best of their way up the sheath and down the long stem, and then proceed without delay to climb some other plant whose blossoms are beginning to give fragrant notice that another pleasant guest-chamber is ready for their reception. Thanks to this diligence, therefore, pollen is brought to the pistils, as soon as they are ready for it, by the "fastest snail-express."

Hitherto we have confined our attention to the welcome guests; but there are unwelcome ones also, and the very snails last considered have two sides to their character. Indeed, the beneficent side is not the one with which we are familiar, being rather a recent discovery, while their mischievous propensities are well and widely known. Even the arums which welcome them as pollen-carriers need some sort of protection against them. They have to be tempted to undertake what to them is really an immense journey, by special attractions, otherwise, being voracious eaters, they would simply begin to devour the first leaf they came across. Then, when they have started, all loitering by the way is sternly discouraged, for arum-leaves are acid, and even poisonous; so there is no temptation to make a meal of them.

Useful as they are to arums and arum-like plants, they are not generally desirable as visitors, and are not often found in flowers, bristles and prickles being enough to turn them back at once. No wingless visitors are generally welcome, for they crawl slowly, lose pollen by the way, by getting it rubbed off them, and are usually so indiscriminate in their tastes that they go as readily to one blossom as another, and it is quite a chance what pollen, if any, they may bring with them.

It is, of course, not to the plant's interest that its pollen and nectar should be taken by insects which plunder without making payment in return, as it is thereby robbed of its means of attracting other and more useful insects. But the useless ones are just as fond of nectar as the useful, just as quick, too, to find it out, wherever it may be hidden, so that many devices are needed to baffle these unwelcome guests.

Human beings can, it is said, detect less than the twenty-millionth part of a grain of musk; but in keenness of scent they are far surpassed by the insect world.

Where is the man who can detect any difference, by smell or otherwise, between cane-sugar and beet-sugar, when the latter is properly refined?—not, of course, such as one meets with in continental hotels. Yet the bees know well, for if the choice be given them, they will take the cane and leave the beet.

And ants are not only as fond of sweets as bees, but will find them out from an immense distance. They have been known to make their way up from the garden to the second story of a house, by means of an outside bell-wire, all for the sake of some dried fruit which they had scented out. They are sure, therefore, to know where nectar may be had, as well as the bees themselves; and yet, what with their crawling, and their tidy habit of constantly cleaning themselves, and their hard coats, which are not suited for carrying pollen, they are some of the least welcome guests that a flower can have.

When the ants do get a chance, they make the most of it, and swarm in greedily; but on the whole they are pretty well kept out, now by one means, now by another.

The snap-dragon, for instance, keeps her mouth so firmly closed that none but the strong humble-bee can force its way in, until, that is, the necessary pollen has been brought. But then, when the seed is made sure, and the ants can do no harm, the lips are unclosed, and they are generously admitted to what remains of the feast, an opportunity of which they do not fail to make use.

Ants, like other wingless insects, prefer to avoid the dew, and so are not astir very early. Some flowers,

therefore, unfold for only a short time during the first hours of the morning and close again by 9 A. M.; and in all probability there is a close connection between the times when flowers open and close, and the hours when their friends and enemies are abroad.

Plants such as the teasel keep off the ants by means of the basins formed by their leaves, which catch the dew as it trickles down their stems, and keep it so effectually as to be seldom empty while the plant is in blossom. Water is completely baffling to ants, and if placed on the stem of a plant thus protected, they run helplessly up and down, and then drop to the ground.

Stickiness, too, of all kinds, is their abhorrence, and is often fatal to them, whether in the form of sticky hairs or sticky juice. The lettuce is one of many plants furnished with a milky juice which is especially abundant near the flowers. If an ant crawls up the stem, its hooked feet are so sharp as to cut through the outer skin, and the juice which at once oozes out hardens rapidly, gluing it to the spot, while the little creature's frantic efforts to clean itself only make matters worse, and it seldom succeeds in escaping.

Many of the plants belonging to the order which contains the catch-flies, campions and pinks, are provided with rings of sticky hairs, and as many as sixty-four small insects have been found at once on one flower-stalk of the red German catch-fly. One can imagine how little nectar would have been left to attract profitable insects if these sixty-four had been allowed to have their way. Ants are usually very wary in their manner of proceeding, and feel their way carefully up the stalk until they reach the sticky ring, whereupon they generally turn round and come down

again; but if they do venture to proceed they are surely lost.

Stickiness is no impediment to slugs and snails, however, for they overcome it by covering it with their own slime. What they do mind are bristles and prickles, which the armor-clad ant can afford to despise.

Pricklets, hairs, and fringes inside the blossom, serve often a double purpose, for they both keep out unwelcome visitors and make the welcome ones reach the nectar by the right way. Thus insects wanting to get at the honey in the spur of the garden-nasturtium are obliged to climb over the fringe on one of its three lower petals, and this they cannot do without coming in contact with anthers or pistils, which they might otherwise pass untouched.

Plants sometimes need protection against even their best friends, the bees, for some of these, in spite of their many good qualities, have a way of trying to reach the nectar by other than the right way—by house-breaking, in fact, instead of by the front door; and others, though willing enough to come in properly, are too small to be serviceable to large blossoms. We have already mentioned how humble-bees bite through the tube of the jessamine, because they find nothing to stand upon while they suck the blossom. But as the jessamine is a foreign flower, this may be thought excusable enough, as there are few insects here able to reach the nectar in the right way.

Some bees, however, really seem to be lazily inclined, for to save time and trouble, they always bite a hole in the columbine and certain other blossoms.

The bladder-campion, however, successfully frustrates any such designs by growing a calyx which is so inflated

that no bee's proboscis is long enough to reach the nectar by means of a hole made in it. Others have calyxes so hard and tough that even humble-bees and ants are baffled by them.

But then, the little bees—where big bees can enter, why not little ones? The foxglove, for instance, gapes widely open; and as stamens and pistil lie close under the upper side of the blossom they are quite out of the way of the small bee, which would pass in and out without touching them if it were allowed to find entrance at all. But an observer who watched the flowers carefully throughout a season in North Wales, where they especially abound, saw many small bees make the attempt but only one succeed. It looks easy enough, but the upper part of the blossom is so smooth as to be actually slippery, and affords no foothold; and the lower part is beset with stiff hairs, which are very embarrassing to smaller insects, though the humble-bee uses them as rests for her feet, and clings to them while she sucks.

It is interesting to watch the methodical way in which a humble-bee visits and explores a spire of foxglove, always beginning with the lowest bell and working upwards; but it may not have occurred to all of us that if she reversed her operations the foxglove's hope of cross-fertilization would be gone. So it is, however, for the foxglove-blossoms not only open gradually, beginning with the lowermost, but the pollen is ripe before the pistils are ready for it; and consequently the pistils of the lower blossoms are waiting for pollen—their own being safely gone—while the anthers of the upper blossoms are discharging it. If the bee began at the top, she would only bring to the pistils pollen from the upper blossoms on the

same stalk; whereas, leaving off at the top, she carries pollen away to the lowest blossoms on the stem of another plant.

Such are a few, and only a few, of the many marvellous provisions for insuring fertilization, for preventing self-fertilization, for promoting cross-fertilization, and for preventing the robbery of pollen and nectar by insects which would not benefit the plant; and to conclude with the words of Professor Asa Gray:

"If these structures and their operations do not argue intention, what stronger evidence of intention in nature can there possibly be? If they do, such evidences are countless, and almost every blossom brings distinct testimony to the existence and providence of a designer and ordainer, without whom, we may well believe, not merely a sparrow, not even a grain of pollen, may fall."

QUESTIONS FOR REVIEW

1. What peculiarities have Alpine flowers and why?
2. How do the different classes of tropical flowers secure their insect visitors?
3. How does the sphinx-moth fertilize orchids?
4. What peculiarity has the bind-weed?
5. In what islands is the lack of insect life made good by humming-birds?
6. What is the humming-bird's food, and how does he get it?
7. Describe the peculiar habits of the arum.
8. Why are ants and snails usually unwelcome visitors?
9. By what means do flowers keep off their enemies?
10. Why is the bee's method of visiting the foxglove especially efficacious.

CHAPTER XVII

SEED-SCATTERING

The great end of a plant's life is to bear fruit. It is for this that roots and leaves collect nourishment, and that insects and birds are attracted to the blossoms by bright colors and the prospect of food. So entirely, indeed, is fruit-bearing the aim of the plant's life, that many plants are dry and withered by the time the fruit is ripe, having given up all their sap, their very life, to bring it to perfection. In any case, whether it last for one year, or two, or many, the plant's life is devoted to making preparation for its offspring.

For this reason few wild flowers are double, as the number of petals must be increased at the expense of stamens and pistils, and without these fruit is impossible.

A cherry-tree covered with double blossoms may be very ornamental, but the gardener grows it for its blossoms only, and does not expect fruit from it. When his object is fruit, however, he sometimes interferes in another way, which has the same result, so far as the plant is concerned; for he increases the eatable part of the fruit, in some cases, as he increases the number of the petals—at the expense of the seed.

A plant's fruit is the ripened ovary, containing the seed; and when the seed is the part used for food, man naturally devotes his attention to that, and cares nothing for the case. From corn, for example, and from nuts, he

wants the seed, not the husk or shell, and therefore he cultivates and increases the size of the seeds. But the seeds of pears, grapes, pine-apples, oranges, dates, are not what he wants; and in some of the best sorts of all these he has so cultivated the ovary or fleshy envelope, at the expense of the seeds, that these have almost, if not quite, disappeared.

But even when the plant is left in a state of nature, and allowed to produce seed in abundance, it often needs further help, if its progeny are to grow up healthy, and vigorous enough to hold their own among their many competitors. The seed must be scattered.

The gardener often finds it advisable to get his seed from some little distance, the plants raised from it being distinctly better than those grown from seed ripened in the same place. This is one reason why it is for the plant's good that its seed should be scattered; and here, of course, we mean by the "plant" the race, and not the individual. But there are many other reasons.

If seeds are dropped close round the parent-plant, in a confined space, they grow up in a crowd, and there is a desperate struggle for existence. Being all of the same species, they all want the same kinds of food, and none have much advantage over the rest. A few seeds may have been a trifle larger, and may produce seedlings a trifle stronger, and better able to battle for what they want, but the difference is usually slight, and the chances are that all will grow up weakly.

Where seedlings are crowded together there must always be a struggle as to which shall survive, but it is much more severe where all are of the same sort. Where they are mixed, some will have advantages. They may

be larger and stronger, or they may be better fitted for the soil and situation. Whatever the advantage may be, those possessing it will speedily overpower their less fortunate rivals, and then, having secured sufficient elbow-room, will grow up strong and healthy.

Plants of different species, when crowded together, are better off in another respect, for they do not all want precisely the same amount of the various mineral foods, and so there is more for all. For this reason it is a very usual thing to sow a grass-field with seed of different species; and the greater the variety, the heavier the crop of hay, because the plants have had a better opportunity of obtaining food.

On this account, therefore, as well as that they may have change of air, it is well for seeds that they should be scattered, or otherwise dispersed. But there are other reasons still.

Some plants need shelter, and are killed by sudden exposure. If they had no means of dispersing their seeds, not only they, the parents, but their whole progeny, might be exterminated, by the removal of trees, etc. Or again, by the draining of a pond, or drying up of a brook, plants needing much moisture might be killed out of a neighborhood, if all their seeds dropped close round them, while they might continue to flourish if they were able to migrate the distance of only a few yards.

In some cases, too, the parent so exhausts the soil, that the children have no chance of thriving, if they grow under its shadow; and then again, if cross-fertilization be an advantage to the plant, even where not absolutely essential, it certainly seems—from experiments made in crossing Indian-corn and beans with plants grown some

miles away—that cross-fertilization with plants at a distance is more beneficial still, the produce being in each case very greatly augmented.

Such, then, are the strong arguments in favor of Nature's plan of scattering her seed far and wide: the plants gain change of air and change of soil; competition is less keen, cross-fertilization is promoted; and when driven by stress of circumstances from one neighborhood, they are able to gain a settlement in another.

Winds, waves, birds, beasts, fishes, and even man himself, are all pressed into the plant's service, and made to act as seed-carriers. But in some cases the plant itself acts, and acts alone, sending her seeds to quite considerable distances.

Many years ago, there was a certain bare, rocky craig near Dunkeld, which the Duke of Athole desired to have planted with trees, though he was quite at a loss how to accomplish it. For as the place was simply inaccessible, no one could climb up, either to sow seeds or to plant saplings. The Duke mentioned his difficulty to Nasmyth, and he, noticing a pair of small cannon in front of the castle, ordered a number of tin canisters, filled them with suitable seeds, and fired them from the guns up the high face of the crag, where they burst, and scattered their contents in all directions. Some few years later there were trees flourishing luxuriantly in all the recesses of the cliff.

Plants cannot perhaps shoot their seeds quite so effectually as this, but in many the seed-vessels split with so much of an explosion that the seeds are discharged to distances which, at all events, remove them from the danger of being squeezed to death in a crowd. The touch-me-not

balsam is one of these. But the sand-box tree of Barbadoes is much more energetic. Its fruit is rather like a small melon in shape, but hard and woody, and when ripe it bursts with a loud report. One of these—dried very gradually in the hope of its remaining intact—exploded nine months after it was gathered, and so violently as to break the wooden box in which it was kept quite to pieces. The seeds were scattered in all directions, but would of course have been carried very much further had they been unconfined.

The fruit of the squirting cucumber has to be bound round with copper-wire when ripe, to prevent its shooting out its seeds.

The pods of the Chinese wistaria also explode with a sharp, loud report, and the seeds may be carried at least thirty feet; while those of the American witch-hazel are shot out to a distance of from twenty to five-and-forty feet. If, when these and other similar seeds are discharged, a strong wind should happen to be blowing, they may of course be carried much further.

Even individual seeds transported by the wind do not always accomplish the whole of their journey "all in a breath"; for the wind comes in successive waves, not in one continuous blast.

Of course, the lighter the seeds, the better chance they have of being carried far, unless they are caught in these ways; and some few seeds, such as those of the orchids, are so exceedingly minute and light, that no mere lull in the wind is enough to make them drop, for they manage to float even in the still, draughtless air of a hot-house. In this respect they resemble the spores of ferns, mosses, and fungi, which can hardly come to the ground at all except

when the air is almost absolutely motionless, so extremely light are they, being, in fact, rather like pollen than seeds. Spores, owing to this extreme lightness, travel immense distances over sea and land, and are to be found in almost all dust, whether of town or country; but in damp weather they are not carried so far, and some of the mosses keep the capsules in which their spores are contained tightly closed except when the air is dry enough to insure them a long journey.

It might seem that large, heavy seeds would be at a disadvantage in respect of wind transport; but as they need a stronger shake to detach them, they do not begin their journey till the wind is blowing with some little force; and then again, being generally borne by trees, and tall trees, too, they start at a favorable height, and are often carried a long way.

But we have been looking upon seeds hitherto as if they were themselves perfectly helpless and inactive, which is very far indeed from being the fact. Many of them have special means of their own for insuring or helping their conveyance from place to place—means which vary according to the carriers upon which they depend for locomotion.

Those which are carried by the wind, for example, have elastic spines, wings, feathery tails, down, hairs, all of which help to speed them on their way, and make it more easy for them to be raised in the air, or blown along the ground.

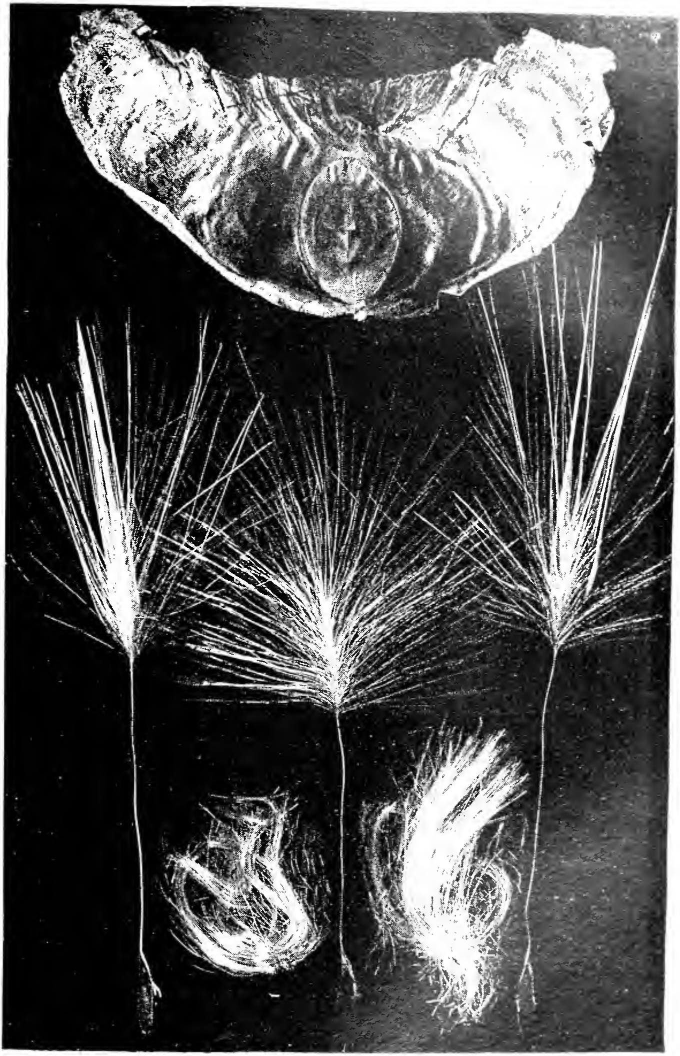
Generally as the lower part of the pistil ripens, the upper part withers, having done its work of conveying pollen to the ovules. But sometimes the pistil-stalk remains attached to the ovary, and is turned to a fresh

use. In the wild clematis, for instance, so far from withering it grows, and not only lengthens out, but becomes silky and feathery, ready to catch any puff of wind, and very easily carried through the air. When it drops, the heavier end, the ovary with its seed, naturally touches the ground first, and is caught at last, perhaps after two or three journeys, in damp soil or moss, or some crack in the earth.

In the dandelion it is the upper part of the calyx which enables the seed to float through the air. A dandelion-blossom is composed of many small florets, each having its own calyx and pistil. The lower part of each pistil is entirely inclosed in its own small calyx, and inseparably united with it. The upper part of this calyx is divided into fine feathery hairs, which at first form a crown to the ovary, and look as if they grew from it. But later, as the ovary ripens, this crown is pushed upwards on a fine stalk, and looks like a miniature parachute, or an umbrella turned inside out, and it catches the wind as easily, the merest breath being enough to float it.

We need not do more than mention the down of the thistle and many other plants, the wind-like appendages of the seeds of the ash, maple, and sycamore, commonly called "keys," and the long, paper-like leaf-scales attached to the flower-stalks of the lime, which answer a similar purpose; or the wing-like expansions by which many seeds are themselves bordered, and which act the part of miniature sails.

The seeds of the water-pink of Ceylon are helped on their way by other means; they are inclosed in circular heads, measuring eight or nine inches across, and beset with elastic spines which stand out in all directions.



WINGED AND FEATHERED SEEDS

These heads are detached from the stalks when ripe, and are whirled over the sands for miles, bounding along on the spines, and dropping their seeds by the way. Often, of course, they are whirled into the water, and there they float, the upper spines catching the wind, and acting as sails.

Water, indeed, plays a most important part in the dispersal of seeds, many of which, if carried only a short distance by the wind to begin with, may continue their journey and travel much further if dropped into river or sea, especially if they happen to reach one of the many ocean-currents.

There are not many seed-bearing plants which grow actually in the water; but one of these, the arrow-head, has seeds which keep afloat a long time, not because they are so remarkably light, but because they are so highly polished as to look and behave as if they had been oiled. They do not even become wet, for water runs off them; and it is not until this polish has been destroyed by much rubbing and long soaking that they can be got to sink.

The seeds of the water-lilies, white and yellow, are kept afloat for some time by means of air-bubbles. Large fruits often float longer than small ones, and could hardly be transported by any other means than water.

Then, however, comes the all-important question, how far the seeds are affected by remaining for some time in water; and here again they vary considerably, some being far more hardy than others.

The coco-nut, for instance, being inclosed in a mass of fiber, floats well, and is able to stand immersion in either fresh or salt water for an unusually long time, without losing the power of germinating; and coco-palms, self-

planted, are the first trees to spring up upon any newly exposed coral-reef, the nuts having been floated thither from some more or less distant coast. When making experiments to ascertain how long seeds might remain in salt water without being killed, Mr. Darwin was delighted to find that some grew after twenty-one days' immersion. Many ocean-currents, as he reckoned, travel at the rate of a mile an hour, so that these seeds might be floated five hundred miles without being any the worse. But, alas! he had overlooked one thing. The seeds had been under water all this time; and as Dr. Hooker reminded him, "If they sink, they won't float!" Seeds vary much as to the length of time they are able to remain afloat, and these seeds could not have been transported at all by water, except under different circumstances, such as while they were still inclosed in their seed-vessels, or even attached to the plant or branch on which they grew.

Some few seeds grew after being kept for one hundred and thirty-seven days in sea water; so that, if able to float, they might have germinated after a voyage of more than three thousand miles—a distance greater than that which lies between Europe and America.

The question was, then, whether there were any way in which they might float; and it was found that though ripe, freshly gathered hazelnuts sank directly they were put in water, they would float for as much as ninety days, and then germinate, if they were first dried.

Now in the natural state, seeds may often be dried by exposure to sun and air before they are washed, or blown, into the water; and they would, some of them at all events, be then perfectly well able to float.

Drying does not answer the purpose with all plants,

however; but out of ninety-four, upon which the experiment was tried, eighteen floated more than twenty-eight days, and some much longer, quite long enough, in fact, to allow of their being carried from one continent to another.

For Mr. Darwin's estimate of a mile an hour as the rate at which ocean-currents travel was a purposely low one; several of the Atlantic currents travel thirty-three miles a day, and some as much as sixty miles a day, so that any of these eighteen plants might have been carried some hundreds of miles, and others from three to five thousand, without their seeds being any the worse for the voyage.

Some seeds appear to have no means at all of getting themselves transported from place to place; but it will generally be found that these are seeds which have been altered by cultivation. The grain of wheat and rye, for instance, falls quite naked from the ear as soon as it is ripe, and sinks at once in water; and this is one reason why neither is ever found wild. Rice is a little better off, for each grain is inclosed in a rough, hard case, which effectually preserves it from injury, and probably in its natural state it was able to float on water. But now that its size and weight have been increased by cultivation, it sinks like the others.

Seeds may occasionally chance to be conveyed across the ocean in drift-wood, without ever coming in contact with the water at all; for stones and small quantities of earth are sometimes found perfectly inclosed; and from the earth thus entangled in the roots of an oak, Mr. Darwin was able to grow three plants.

But again, there is another way in which seeds may

escape contact with water: dead birds, having seeds in their crops, may now and then escape being devoured, and may be floated long distances by river or ocean currents; and as many seeds retain their vitality after being in a bird's crop for thirty days, some may be conveyed in this way from time to time.

The so-called "goose-wheat" of Canada was first sown from grain found in the crop of a wild goose which was shot on its way, probably from Alaska, or the Russian settlements on the other side of Behring Strait.

QUESTIONS FOR REVIEW

1. What are nature's arguments in favor of seed-scattering?
2. Give instances of plants which scatter their seeds by explosion.
3. How are many seeds fitted especially for transportation?
4. Give the results of experiments showing that seeds may be carried far by water.
5. How are these seeds sometimes preserved from contact with water?

CHAPTER XVIII

SEED-CARRIERS

The seed-carriers now to be considered are employed for the most part with as little reference to their own wills, and often with as little knowledge on their parts, as the winds and waves. The seeds simply make use of them as carriers, whether they will or no, and that no matter whether they be birds, animals, or even men; for all are pressed into the service, and know, for the most part, nothing of what they are doing. We are, of course, not here speaking of man's voluntary importations, but of his involuntary ones, which are probably almost as many.

There are, however, some few voluntary carriers among both birds and animals—carriers who, though in one sense quite unaware of what they are doing, yet for purposes of their own do carry seeds from one place to another, not very far probably, but often the distance of a few miles.

Some birds, for instance, take a positive pleasure, as it would seem, in carrying things about for the mere sake of carrying them; and the propensity is especially strong in the crow tribe, including not only crows, but rooks, jays, magpies, and jackdaws, many of which also have a great love of hiding as well as carrying.

On one occasion a large number of fowls, destined for New Orleans, had been collected at some spot up the river, and as the boat which was to convey them was not ready,

they were turned out into the woods for about a week to shift for themselves. During this time they laid about two thousand eggs daily, a fact which seemed immensely to interest the crows of the neighborhood. For whether with a view to eating them, or simply from a love of being busy, they devoted themselves to carrying the eggs away and burying them in a field more than half a mile off on the other side of a creek. A month or two later, when the field was plowed, the eggs were turned up in hundreds, and being still perfectly good, supplied the laborers with many a meal.

But now, supposing that the crows had buried acorns instead of eggs, and that the field had been waste ground, where plow and harrow never came, might not a small forest of oaks have sprung up? and may not many a plantation of oaks, beeches, sycamores, and other trees have been planted in a similar way?

A certain pine forest in Minnesota, for example, on being cut down, was at once succeeded by oaks; and a similar thing is said to have occurred in North Carolina, with nothing in either case to account for it. The oaks seemed to have grown of themselves; but since oaks must certainly spring from acorns, it seems at least possible, and indeed probable, that crows may have been the planters.

When the crows assemble in their hundreds to hold a "powwow," or parliament, then is the time when they do their sowing on a large scale; for true to their usual habits, many, if not all, bring and drop something. The place chosen for the assembly is always open, and more or less bare, and afterwards the ground may be seen strewn with walnuts, hickory nuts, acorns, sticks, and

other rubbish. A certain field which had been left to itself for some time was found to be full of young bur-oaks, there being no parent tree anywhere near from which the acorns could possibly have been carried, even by a high wind.

Now, how could these have been planted, save by birds? Pigs simply crunch up and eat nuts and acorns where they find them; and though the squirrel sometimes carries them several hundred yards, it seldom does more, while the field-mouse certainly does not lay up her winter store very far from where her crops grow. Besides, neither tree-squirrels nor mice act in concert, and planting on so large a scale must have required a small army to accomplish it.

No doubt, however, both tree and ground squirrels, as well as mice, are responsible for the planting of many a single nut-bearing tree; for sometimes they may be startled, and made to drop their treasure before they reach home; some may forget their storehouse, and some may die before it is empty.

But the gray tree-squirrels may have done more, for unlike the red and the ground squirrels they bury their winter store of nuts and acorns separately, one by one, about a couple of inches deep; and though they have such good memories as to be able to find them again, even when buried under a foot of snow, no doubt in many cases accidents have happened, and their stores have been left undisturbed, and would have excellent opportunities of growing. The number of these little animals in North America was something extraordinary in bygone times; for in one year (1749) six hundred and forty thousand were destroyed in Pennsylvania alone. They may well,

therefore, have done a great deal of planting, though they would probably not carry their nuts far.

The nuthatch often plants quite a colony of young beeches around its haunts; for it has favorite trees to which it resorts, after twisting a cluster of nuts from the bough; its object being to fix the nuts in some crevice of the bark where it may hammer at them. Very often, however, it fails in the attempt, the nuts fall to the ground, and under favorable circumstances, germinate.

Monkeys, also, sometimes carry nuts and fruits to a distance before eating them; and if meantime their attention be caught by something else, they will probably drop and forget all about them. Brazil-nuts, for instance, are inclosed in such a very hard, strong outer case that no monkey can get at the contents, except by hammering it for a long time against a rock, or a hard log of wood, neither of which is always to be found close at hand.

So much, then, for the voluntary carriers, whose work is but small and limited compared with that of the great army of involuntary carriers.

Look, for example, at a dog when he has been hunting in a ditch, and see how the burdocks and goose-grass, or cleavers, have taken advantage of him, and made him act as carrier for them.

Now, what is true of the dog in this respect is true also of many animals, wild and domestic, including man himself. The fleece of sheep, the fur and hair of other animals, the feathers of birds, the clothes of human beings—all answer the purpose of these hooked, barbed, and thorny fruits, by giving them something which they can lay hold of.

We have abundant proof of this in the way in which

more than one plant has been introduced not only from one continent but from one hemisphere to another within recent times.

The "Bathurst bur," among others, is a striking example of the successful emigrant. Growing in Patagonia, it got itself conveyed to Australia, where it has flourished ever since in the most rampant manner. The first step was to hook its burs into the tails and manes of horses, which it did most effectually; and then, as chance would have it, some of these same horses were imported into Australia, burs and all, for so thoroughly were they entangled that the animals had not been able to shake or rub them all off, even during the voyage. Some no doubt were got rid of, but enough remained to make a fresh start in the new country; and they did it with such energy that within a few years it was found necessary to pass an act of Parliament "against the growth of thistles," and all persons allowing them to remain on their land, or even on their half of the road, were made liable to heavy fines.

But birds are the great carriers; and the migrants, especially, transport such seeds as lay hold of them to much greater distances than quadrupeds ever travel, at least without the help of man.

There is a species of sedge which grows by the water in the highlands of Jamaica, whose fruit is provided with long bristles, something like a shepherd's crook, the hooked part being so closely fitting and elastic as to grasp the finest hairs, if drawn across the back of the hand. It grasps them so tight, moreover, as to pull them out sooner than let go. The highlands where this sedge abounds are the spots generally first touched by migratory

birds, and in some cases small birds are caught and held so firmly by the sedge's hooks as to be quite unable to escape. Larger and stronger birds of course get away, but must carry many of the seeds with them; and these, as the bristles wither and relax their hold, are dropped by the way. Accordingly the sedge is plentiful all along the track followed by these birds—that is, the east coast of North America and the adjacent islands, among which the Bermudas especially are visited by large numbers of these migrants.

Birds, such as the puffins, which burrow in the earth, get their feathers covered with vegetable mold, which is sure to contain spores and seeds, some of which may cling long enough to be carried at least part of the way, when the birds leave their inland nesting-places for the coast, where they spend the greater part of the year.

Birds, it is true, are generally very particular in keeping both beak and feet clean, but still sometimes they are found with little cakes of earth adhering to them; and seeds are so very common in all soil, that some no doubt are transported in this way. Indeed, eighty-two plants have been grown from the earth taken from the leg of a single partridge, and that after the earth had been kept three years. This partridge had carried as much as six and a half ounces of earth on its leg; and what one has done, others of course may do, and probably have done. Still, dirt on feet and beaks is rare.

The birds most likely to have muddy feet are naturally the waders, and those which frequent the edges of ponds and moist and muddy places. And these, if they carry away mud, are certain to carry away seeds also, for damp soil catches and keeps the seed dropped upon it in a way

that dry soil cannot. From about a breakfast-cupful of mud taken under the water from the edge of a small pond, Mr. Darwin succeeded in raising five hundred and thirty-seven plants.

Now, the birds which frequent bogs and marshes and other muddy places are also the very birds which wander most, the migrants in fact, chief among which, for the wide extent of its journeyings, is the woodcock; for there is hardly any island, however remote, but the woodcock finds its way thither, and no doubt it has carried in its time many a seed, which has been dropped again in soil as muddy as that from which it was taken, and has therefore had a good chance of establishing itself.

But though birds convey seeds both in their feathers and in the mud on their feet, they no doubt convey many more in their crops. There is no gastric juice or anything else in the crop to injure the seeds in any way, and when a large supply of food has been taken, the grains do not all pass into the gizzard for twelve, or even eighteen, hours, in the course of which time a good deal might happen. Birds, for example, are occasionally blown the whole way across the Atlantic, the wind carrying them on at the rate of thirty-five miles an hour; and they might well, therefore, be carried five hundred miles before all the grain had passed out of their crop, if they had just had a full meal.

Supposing them to be blown over land instead of over sea, or to reach land after a few hours, they might then be pounced on by the hawks, who are always on the look-out for weary travelers. These, like the owls, bolt their prey whole, and after some hours disgorge pellets of feathers and other undesirable matter, among which

might be the seed in the crop of their victim, still uninjured. This, indeed, is no mere speculation, for it has been found by experiment that such pellets do contain seeds, such as oats, wheat, hemp, millet, clover, and canary-seeds; all of which may be capable of germination.

Seeds vary very much as to their power of resisting digestion. Many are, for the most part, quite digested, but there are others which are protected against digestion by a covering so hard, or so tough, that it is a real help to them to be swallowed, as they germinate more readily when this covering has undergone some amount of softening.

Seeds, for instance, which are swallowed, not for their own sake, but for the sweet flesh surrounding them, are more or less hard, and some stone-like. Even the seeds of elms, firs, and ashes often escape not merely uninjured, but actually helped by being swallowed; and the same is true, in a much more marked degree, of the stones of the cherry, sloe, raspberry, blackberry, and the seeds of the apple, and the tiny nuts of the strawberry.

In some cases birds render a positive service to man also, by swallowing and scattering the seeds of plants which he cultivates. All the present "pimento walks" of Jamaica, as the plantations are called, have been sown by birds; for though the plants can be raised in nurseries in large numbers by careful treatment, the planters are of opinion that the seeds are better prepared by the birds. And why should they incur the trouble and expense of this "careful treatment," when the birds do all that is necessary?

When a new "walk" is wanted, all that is necessary is to inclose a piece of waste ground near an old "walk." The birds eagerly eat the fruit when ripe, and the seeds are dropped, with the result that twelve months after the first rains abundance of young plants are to be seen growing vigorously in all parts of the new inclosure. If not inclosed, the plants would be eaten off or trodden down by wild animals; but this amount of protection is all that they require.

Some trees seem to be entirely dependent upon birds for getting their seeds scattered, and cannot spread without them. The red cedar is apparently one of these; for though introduced into Indiana nearly fifty years ago, it did not run wild, and was not to be found in the forest, until some of the birds became sufficiently familiar with it to venture to eat the seeds. During the last few years numbers of young saplings have made their appearance, and it is likely to be one of the forest-trees of the future. The seeds of the red cedar have so hard an outer covering that gardeners find it well to scald them before planting; and it is therefore, no doubt, a great advantage to them to be swallowed.

How, except by being swallowed by birds, does the mountain-ash berry get conveyed to the top of high walls, where young trees may sometimes be seen growing? How, save in this way, does the mistletoe reach the top of the oak? or how do the wild-rose and privet find their way to the walls of Cologne Cathedral? The reader may possibly be inclined to add another "how" to the series, and ask how, when they get there, do they manage to find soil to germinate and grow in? But as already remarked, a very little soil is enough for seeds to sprout in; and

this, in the case of buildings, is provided first, probably, by the decay of lichens and mosses and of the stone itself, and also by the wind, which conveys many a little pile of dust into sheltered nooks and corners. As for the mistletoe, being a parasite and living by the labor of others, it has no difficulty about soil, and makes itself at home not only on the oak, but on other trees, above all on the apple.

The fruit-eating, and consequently seed-carrying, birds of the tropics are the countless multitudes of the parrot tribe, which usually feed in flocks of thousands, and wander far in search of food; and besides these, there are many fruit-eating pigeons, hornbills, and others. Nor must the immense flocks of large fruit-bats, or flying foxes, be overlooked; for their numbers are so enormous that they often take hours to pass, while their depredations in the orchards are carried to such an extent as to make them one of the greatest pests of the tropical fruit-grower of the East. In his absence, however, the fruit-eaters have done, and do, much valuable service in the way of carrying seeds.

Seed cannot be sown to any purpose until it is ripe, and it would therefore be simply wasted if the birds carried it off too soon. But it is safe enough from them while it is unripe, for the eatable part, the flesh surrounding the seed, is unripe, too, as the birds very well know, and they leave it severely alone.

Red, yellow, purple, and black are the most usual colors of ripe fruit, and these the birds seem, therefore, to understand best; for they seldom touch white currants till the red are gone, though the white are the sweeter of

the two; and they have been observed to leave unnoticed a holly-tree bearing yellow berries, while they stripped other trees near of their ordinary red ones. Yellow holly-berries being uncommon, these were probably considered to be still unfit for eating.

But to mention, in conclusion, some of the other seed-carriers besides the birds. Among these must be reckoned fish, locusts, cattle, and perhaps above all, pigs.

Fish swallow the seeds of many water and land plants, including even the large seeds of the water-lily; but being confined to their own pond, lake, or river, their range is necessarily limited. When, however, they, in their turn, are swallowed by herons, storks, kingfishers, and other fish-eating birds, the seeds may be conveyed to much greater distances and be dropped quite uninjured. Some large seeds of the great southern water-lily, for instance, found in the stomach of a heron, had probably first been swallowed by a fish.

The locusts which frequent parts of South Africa are believed by the farmers to have introduced there various new plants which are injurious to the grass; and it is a fact that undigested seeds, capable of germinating, are found in their droppings.

Cattle and pigs, but especially the latter, are responsible for the rampant way in which apple-trees are now running wild and forming extensive groves in the Pampas. The pips are so well protected as to be indigestible even by a pig; and the same may be said of peach-stones, which have also been extensively scattered in New Zealand and elsewhere, by similar means and with similar results.

QUESTIONS FOR REVIEW

1. Show how crows, squirrels, ground-mice, etc., serve as seed-carriers.

2. How have seeds been transported in the hair of animals? Illustrate.

3. How by external contact with birds?

4. Give instances of the distribution of seeds used as food by birds.

5. By what other animal agencies are seeds scattered?

CHAPTER XIX

CHANCES OF LIFE

Of all the wonderful things in nature, surely a seed is one of the most wonderful. How dead and helpless it looks; how very little it tells us about itself, and yet how very much is wrapped up in it! Seeds especially small seeds from the same plant, look just as much alike as grains of sand. Indeed, peas have become proverbial; and we say "as much alike as peas in a pod," when we mean that things, or people, are quite without individual character.

And yet each seed, even the smallest and most dust-like, has a character of its own—a character which distinguishes it not merely from other seeds of different families, but a character which distinguishes it also from all its nearest relations, even from those which grew in the same pod with it.

Probably it is only want of sight which prevents our seeing the difference between one seed and another, for certainly even the most careless observer will admit that he has never yet found two perfectly identical plants. Not even two peas, taken from the same pod, will grow up precisely alike.

But as long as the seed is kept from its natural bed in the earth, it not only looks dead, but is dead to all intents and purposes, for it has no means of showing that it lives—dead, however, with a possibility of life, which

generally grows less and less the longer it is left unburied. When the life has died out of it wholly, it still looks much the same as before, at least to the unpracticed eye.

As to living seed, if it be one that we know, we can tell at a glance what sort of plant bore it, and what plant will spring from it. But if it is a seed that we do not know?

Well, even then we may be able to tell by the look of it what family it belongs to, whether it is starchy or oily, whether it will have two seed-leaves, like a bean, or one, like corn. But our knowledge will not carry us much further. In many cases it will not even tell us whether the forthcoming plant will be a tree, or a shrub, or a lowly herb. To the inexperienced, many of the smaller seeds especially look very much alike; and there is certainly no such difference in their appearance as would lead one to guess at the great variety of plants which will spring from them; and even the wisest knows very little about the why and the wherefore of the matter.

For why should the small seed of the elm produce a tall tree, and the large seed of the gourd only a short-lived, weak-stemmed, creeping plant? Why should one bean grow to the height of a few inches only, and another climb up several feet? Why, again, should an acorn always produce an oak, and not some other tree? All that we can answer is, an acorn has oak-life in it. But we might as well say we don't know, for all the light this throws upon the subject.

Look now at these seed-pods and seeds. We may know that they have been taken from plants of the great cabbage family; but the family likeness is so strong between them that we should probably be puzzled to say

which would produce red cabbages and which green, and from which will come crinkle-leaved savoys, curly-leaved kale, Brussels sprouts, broccoli, or cauliflowers. All these are but varieties of the cabbage, though they are so very different in appearance; and as long as they are only seeds, they are so nearly alike that their secret is quite safe from ordinary people.

Even when we know that certain plants will spring from certain seeds, we are in many cases quite unable to tell what the color of the blossom will be. There is no difference at all to be detected in the seed, yet one seed will produce blossoms of one color and another of another. But why?

For instance, from the seed of the verbena, phlox, and sweet-pea, we know, because it has been so in the past, that we shall get verbenas, phloxes, and sweet-peas; and we may go a step beyond this, and say that there will be no quite blue flowers nor any yellow ones among them. This we know from experience. We know, too, that, though the seeds of each sort look so exactly alike, no two plants will be absolutely similar, and the blossoms will vary much. Some of the pea-blossoms may be pink of different shades, others pink and white or purple, though they grow side by side; and there will be still greater variety in the colors of the phloxes and verbenas, some of which will also have white eyes, and some not. But we cannot tell by looking at it which seed will produce which blossom.

And even if, in some cases, we should be able to do this, we are still not a whit nearer solving the mystery of the how and the why. We may conclude that there is some minute difference in the food which the roots take

up, according as the blossoms are of one color or another; for we know that the pink hydrangea will turn blue if supplied with an extra amount of iron; and we may argue that, though the peas all look alike, one has that within it which causes it to take up what will produce pink blossoms, and another that which will produce purple ones. But it is a mystery still.

We may prevent their growing at all, we may keep them till the possibility of life has died out of them; or, though we let them grow, we may prevent their blossoming; but if allowed to grow and blossom without interference, in their native soil, one will bear its pink and another its purple blossoms without fail.

But if the seed tells us nothing as to the color of the blossom which will spring from it, it often tells us also just as little as to the size of the plant which it will produce, and the length of that plant's life.

Here, for instance, are three seeds of different sizes, but all belonging to the bean-like or leguminous order of plants. Supposing that we had never seen them before, and were told that one would produce a tree, another a shrub, and the third a dwarf annual, should we be likely to guess that, from the two smaller seeds would grow a laburnum and a broom-plant, while from the third, which is so many times larger, would spring only a broad or Windsor bean?

Some of the orchids bear large blossoms, and others large masses of blossom; yet their seed is almost dustlike. The seed of the lobelia and of the scented tobacco is about equally minute; but from the one springs a plant only a few inches high, with quite small blossoms; and from the other, one which grows to a height of

two or three feet, and has blossoms at least four inches long.

Then again, size of seed has nothing at all to do with length of life. The large broad bean has life only for a single season; the small laburnum-seed has life which lasts for years. The lupin, another leguminous plant, is both an annual and a perennial; but strange to say, the perennial lupin bears the smaller seed, though it not only lives longer, but is also the taller plant, and produces more blossom of the two.

An oak may live as many centuries as a bean does months, or more; but who can say why?

The famous chestnut-tree on Mount Etna is said to be ten hundred years old; and among other ancient trees, whose age is more or less well attested, there is an oak reputed to be sixteen hundred years old and a walnut of nine hundred; there are olives which are believed to be two thousand years old; and there is at least one tree in the East which tradition affirms to be even six thousand years old! But again, why an olive should outlive an oak, who can say?

There is a great difference, also, as to the length of time during which the seeds themselves retain their vitality or power of germinating. Most of them look equally lifeless; but in some this mysterious power lasts much longer than in others, and this, too, with very little reference to their size, though large seeds, especially oily seeds, have some advantage. The seed of the coffee-berry, for instance, is worthless unless planted without delay directly it is ripe; and willow-seed is said to live only a fortnight after ripening, or less if it is allowed to become dry. Seeds of melon and geranium, on the other

hand, have been known to germinate after being kept, merely wrapped in paper, for thirty years. It is believed that if melon-seeds produce plants at all after being kept for some time, their crop of fruit will be all the larger; but they are commonly supposed not to live longer than seven years, and even within this period the longer they are kept the smaller is their chance of germinating considered to be.

Cases, however, have been known in which certain seeds, quite small seeds, too, have kept the life in them not only for years, but for centuries, and even millenniums. We are not alluding to the famous mummy-wheat; for the grain of wheat, being quite unprotected except by a thin husk, loses all power of germinating in a few years at most; and none of the interesting stories told of wheat raised from grain found in Egyptian tombs have ever yet been satisfactorily proved.

Grain taken from mummies has germinated sure enough, but it has been grain recently introduced by the Arabs! In one instance the plant raised bore oats; but this was unlucky, for oats were not known to ancient Egypt; and in no single case has any success attended the innumerable attempts made to raise plants from genuine mummy-wheat. But seeds found in Roman tombs have not only germinated, but produced plants.

Of all well-authenticated cases, however, the most remarkable is that of the seedlings raised by Dr. Lindley, in Chiswick Gardens, from raspberry seeds found in Celtic tumuli perhaps some two thousand years old. Raspberry seeds have very hard coats, it is true, and these seeds were safely buried from the air, and beyond the reach of any great changes of temperature; but yet that things so

small should have been able to preserve living germs within them for so long a time is a wonderful proof of their great tenacity of life.

Generally speaking, it seems that the seeds of wild plants have the advantage over the cultivated in this respect. They retain their vitality longer; but then, on the other hand, there are not so many of them. Cultivated plants usually produce most seed—except, of course, where blossoms have been doubled or fruit improved at its expense.

When one considers the vast quantity of seed produced, and the ample contrivances for scattering it, it is surprising to find that, after all, many plants do not increase their numbers at all. There are just about the same number of them now that there were years ago—neither more nor fewer.

Take, for example, the common wild spotted orchis, a single plant of which often bears as many as thirty seed-vessels, each containing six thousand two hundred seeds. Suppose that there were four hundred bad seeds to each capsule, twelve thousand in all, which is a fair allowance, one plant might still be the parent of one hundred and seventy-four thousand others—enough to cover nearly an acre of ground if the plants grew just far enough apart to allow a proper amount of space to each. The descendants of these, again, might more than cover the Isle of Anglesey, and the great-grandchildren of the one original plant would more than clothe the entire land surface of the globe!

This calculation was made by Mr. Darwin; and yet, as he goes on to observe, the plant is actually not increas-

ing at all in most places, although it is a perennial, and although its seeds are so minute as to be easily wafted to a great distance by the wind. So, then, only one seed out of the thousands borne by a single plant can come to anything, and even that not every year, but only once in several years; for as each plant lives some years, there must be an increase in its numbers if but one new plant grew up every year.

That the seeds are scattered, and widely scattered, is unquestionable, for seedlings have been found eight or ten miles away from where any plants grew; but it is equally certain that there is some effectual check to the plant's increase, though what that check is remains unknown.

It is plain, therefore, that the mere scattering of the seed, however necessary as a first step, is far from being enough to secure that the plant shall be able to establish itself in a fresh locality; and the farther the seed is carried the greater the risk it often runs. Some plants are much better able than others to adapt themselves to altered circumstances, and these, of course, make the better colonists; but even they may be quite unable to effect a settlement, simply for lack of space. Others find that soil, or climate, or situation do not suit them, and soon die out for that reason. Others, again, though they may find ample room, and all things else to their liking, are quite unable to become permanent colonists because they cannot fertilize themselves, and if there are not the right insects to do it for them, they cannot produce any seed. Such plants as have more than one "form," and such as bear pollen and ovules on separate individuals, run, of course, especial risks when they migrate, as one is generally helpless without the other.

In the matter of soil, too, a very short distance often makes a great difference. The bee-orchis, for example, grows plentifully on the chalk in Surrey, and one year it suddenly made its appearance in a clayey field near Thames Ditton, where it had never been seen before. About a hundred plants blossomed in this one field, and nowhere else in the neighborhood. But they gradually dwindled away, and in the course of six or eight years all had entirely disappeared. The seeds had probably traveled to the clay-field in some chalk which had been brought from another part of the county, but the colony could not be a lasting one for some reason—most likely owing to the change of soil, and perhaps also of situation.

European plants, to the number of more than a hundred and fifty, have been quite successful in New Zealand, and are thoroughly established; but it is remarkable that while so many European plants have made themselves at home there, only two or three Australians have managed to do so. Yet Australia is nearer than Europe, and the intercourse between the two countries is much more close and frequent than it is with Europe. Moreover, Australian seeds have been purposely and extensively scattered in New Zealand, among them being, we may be sure, the seeds of such common kinds as those of the acacia and eucalyptus, yet none of these trees are to be seen growing wild.

It is the same with our own garden-plants. How many there are which, though they grow in the garden without any special care, and bring abundance of seed to perfection, yet never run wild, even to the extent of appearing on just the other side of the wall or hedge! Yet it is impossible to suppose but that the seed is often carried

beyond these limits; and weeds make their way in without difficulty.

In considering what becomes of the vast amount of seed which is annually ripened, we must, of course, bear in mind that a great deal is consumed as food—luckily for us; for if there were no seed-eating birds, we should be overrun with thistles and other weeds. Some seed also falls upon soil which does not suit it; some requires burying, and gets killed by remaining exposed; some cannot germinate without special preparation of itself or the soil, or both; still more, if transported to a distance, will find the climate unsuitable.

But in many cases want of space is the only obstacle, and a very serious one it is. There is generally plenty of room for weeds in a garden, and they are not slow to take advantage of it; for there is a good deal of crowding on the other side of the wall, where, in fact, a constant struggle for existence is going on, and only the stronger survive. Seeds falling upon ground already covered, and thickly covered, with vegetation, as a hedge-bank generally is, have but little chance. In fact, they hardly reach the soil at all, the great majority of them.

Look among the long meadow-grass, and you may often see hundreds and thousands of downy seeds caught among the stems and suspended, each with its seed pointing downwards, ready to take advantage of any crack in the soil in which to insert itself, but quite unable and unlikely to reach it. And even of the seeds which do reach it, how many must find that the first-comers are stronger and better fitted for the situation than themselves! and so, even if they spring up, they are speedily overpowered and crowded out.

The number of seeds produced varies enormously in different plants. Orchids produce them at the rate of thousands to each blossom; and some of the foreign species go far beyond this, a single seed-vessel containing more than a million and three-quarters of seeds. The blossom of an oak, on the other hand, produces but one seed. But the advantage is not all on the side of numbers; for the greater the number the smaller the size; and the smaller the seed the smaller the germ, and also the smaller the supply of ready-made food with which it begins life. A large seed, such as a bean, has a large, strong germ; and its two thick seed-leaves, which are really store-cupboards, can supply the seedling with plenty of food, so that it starts with much in its favor. And so ten large seeds will often, it is said, yield more plants than some thousands of small ones.

Neither the acorn nor the chestnut, when it has left its shell, has anything to protect it except its color, which, being like that of the earth, or of dead leaves, may sometimes enable it to escape notice as it lies on the ground; and if but one escapes now and then, at long intervals, once in a few centuries, the stock will be kept up, though not increased.

Small seeds have a better chance in some ways, as they are more easily sheltered, and hidden from the bright, keen eyes of the birds. A bed of damp moss is a capital hiding-place; and so are the cracks which open in the soil when the earth is dry; for these close up again when the wet comes, and the seeds are safely buried out of harm's way. Cracks may often be seen full of seeds.

Still, "if you want a thing done, do it yourself," is an excellent motto even for seeds, and it is an advantage to

be independent even of cracks; this is what some seeds are, especially a good many grass-seeds; for instead of waiting to be buried, they set to work and bury themselves.

The seed of the grass Aristida, for instance, is inclosed in a couple of husks tipped with bristles, each divided into three fine tails, six or eight inches long, which stand out in different directions more or less at right angles to the seed. When the seed falls to the ground the tails keep it upright, and as they dry and twist, they make it turn round and round on its point, which is barbed with flint; and so it bores its way into the earth, the barb holding it fast, so that it cannot be blown away by wind.

Another self-burying seed is that of one of the crane's-bills, which is nearly related to the geranium. The fruit of this little plant consists of four or five miniature arrows, which are the hardened and much lengthened carpels, each having its ovary (containing a single seed) at the lower end. At first they are fitted closely together round a central spike, and form the "beak," with which we are all familiar in the geranium. But when they are ripe, they separate at the lower end, and begin to twist like a cork-screw, still holding together at the tip, however, for a time. Each arrow is fringed on the inner side with short stiff hairs, and the ovary is pointed and barbed in a special manner. They are readily carried by the wind therefore, besides also clinging easily to the coats of animals; and when at last they drop singly to the ground, the barbs catch in the soil and hold them fast. The shafts of the arrows twist more and more the drier they grow, and as they twist, they turn the seed deeper and deeper into the ground.

Some seeds have many more difficulties in the way of

their growing than others. For with some, it is absolutely necessary that they should be buried before they can even begin to germinate; while others, though they may be able to germinate without help or preparation of any kind, find it by no means easy to do more than make the first start.

With some, germination is an easy matter enough, all that they need being a little moisture. Such is the mustard-seed, which will sprout, and even grow for a time, on any damp surface; a piece of flannel, or even the outside of a porous earthenware jar will do, if only this is kept filled with water. Other seeds begin to shoot even before they leave the parent-plant. The seeds of a species of convolvulus put forth quite large leaves before they burst the pod; and in hot climates, the seed of the water-melon sometimes grows in like manner, within the fruit.

Brazil-nuts also begin sprouting before the hard outer case in which they are inclosed shows any sign of decay; but though they may all sprout, only one of the whole number seems to have a chance of doing more under ordinary circumstances. There are from twelve to fifteen nuts—or, strictly speaking, seeds—in each ovary or case, which is filled with the matted roots sent out by one and all. At the lower end, where the fruit was attached to the stalk, there is a small opening, and the fortunate individual which gains possession of this exit may eventually burst the case with its roots, and so make its way into the soil. But the shell of the case is extremely hard, and so far as has been observed, it is not often that even one single plant succeeds in freeing itself. But then, on the other hand, if the shell were less hard, none would probably ever escape the hosts of animals ready to devour

them; for sprouted nuts, taken out of the case and planted, have been found to be all dug up and eaten by rats.

With the exception of the sugar-maple, none of the forest-trees or the evergreens seem to have children growing up round them in Indiana. Seeds of white pines, firs, American poplars, etc., when they fall upon the scattered leaves of the parent-tree, simply lie there and die; and their almost only chance of life seems to be when they fall upon some little bed of earth made by the hogs, which root about among the leaves and turn up mold while they are searching for worms.

One would not suspect hogs of doing any useful work of this sort; but these animals, which have been turned loose in the woods, do seem to have planted many clusters of young poplars, for the edge of the trees just corresponds with the date when the pigs were first brought into the settlement.

A change deserving of notice has been wrought in some parts of the Riverina, New South Wales, solely, as it would seem, by the introduction of cattle. In the old times there were not animals enough to eat the grass down; and so when it became ripe and dry, it was easily set alight by a chance spark from the fire of a native. The natives were, indeed, suspected of firing it on purpose to insure a fresh crop to tempt the kangaroos within their reach. Any seeds of eucalyptus or other trees were either killed in the conflagration or by exposure to the weather, for they lay on the surface of the ground, with no animal sufficiently heavy of foot to tread them in; and it would seem that their only hope could be in chance cracks. Trees were accordingly scarce in these parts;

but the scarcity evidently arose, not from want of seed, but from want of opportunity for its growth. For all now is altered: the cattle tread the seeds in, and don't, apparently, eat the young plants which spring from them; for dense forests and scrubs have arisen—not to the satisfaction of the graziers, who would prefer grass alone.

Some seeds appear to have only an occasional chance of germinating in a state of nature; for they must either be scalded, or scorched, or very hard frozen before they can sprout at all, and even then they cannot prosper unless they have a clear field, with no other plants to interfere with them. This is the case with the seeds of the black locust-tree, which are easily carried by the wind, and are so very hard that they may lie exposed for years without being any the worse for it, it is true, but also without being able to germinate. If they were less long-lived, they would probably die before their opportunity came. But if, when a clearing is made in the forest, the trees should be fired and the ground burned bare, as it is sometimes, then comes their long-waited-for opportunity, and up they spring in numbers wherever the fire has passed.

The seeds of a certain species of cedar could not be got to grow at all at the Cape until they had been thoroughly boiled. Such very hard-coated seeds are well protected against injury, but in a state of nature they must be dependent upon fires, frost, or perhaps on being swallowed, for the opportunity of growing.

Other seeds, again, though they require no special preparation of themselves or the soil, are quite unable to germinate unless they get rain immediately after they have fallen, and that, too, continued for some little time.

Thus the "soft maples" planted in the streets of Rock-

ville, Indiana, though they have borne seed, have never succeeded in sowing themselves till within the last few years, as a single day's exposure to the hot sun is fatal both to seeds and seedlings, and even daily watering often proves insufficient to keep the latter alive. In the wild state they spring up only in very moist or watery places, though later on they will bear transplanting to dry soil.

One year, however, there was a storm which shook down such a quantity of seed that the streets of Rockville were yellow with it. Then followed several days' rain, with sunny intervals, and the seeds sprouted everywhere, all over the streets, in the yards and the gardens, as thick as weeds—a sight never seen before.

How is it that European weeds have spread so extensively in the United States, while Australian seeds, widely and purposely scattered in New Zealand, have gained no footing?

First and chiefly because in the one case there was a vacancy, and in the other there was none. The vacancy in America was not natural, but caused by the cutting down of forests and the dying off of the undergrowth, which was killed by sudden exposure. Of course, there were plenty of plants in America which would have stepped in and taken possession in time, but they were too far off, on the plains and prairies of the great Mississippi Valley, to do it quickly enough, and meantime the foreigners arrived. Weeds from Europe were introduced with grass seed and corn seed, and in other ways, and when the forest lands were turned into pastures and fields, these weeds had as good a chance of thriving as they had at home.

It would be a different matter if they were to arrive

now, for meantime other changes have taken place which have made it easier for plants to come from the West, and they do come. New Western plants migrate, it is said, almost every year into the Eastern states.

And how do these new plants travel? By rail, to be sure, in accordance with the spirit of the age. They come in the coats or in the food of cattle going to market, and they take advantage of the bared railway borders, which are such excellent nursery-grounds. The great railroads run east and west, and as the prevailing winds are westerly and very strong, the plants of the West are now amply provided with the means of transport. The seeds also find vacant spots on which to alight, and by which they may break the journey, and finally they are transported into a climate not greatly unlike their own, so that they have much in their favor.

Plants traveling east and west have a much better chance of finding a climate to suit them than those which travel north and south, except, of course, such as cannot thrive without sea air, like the holly, which cannot live at all more than a hundred miles from the coast. But of the plants which travel north and south, those generally have the better chance which travel from a cold climate to a warmer one. Increased warmth is better borne than increased cold, and the plants of temperate latitudes have stronger and more vigorous constitutions, such as give them great advantages.

See, for instance, how they have thriven in the Pampas district of South America, in some parts of which there is hardly a native plant to be seen for miles, so completely have the new-comers ousted them. For the giant "thistles" and the luxuriant clover, already described, are

not natives, but colonists. The fatherland of the artichoke family, to which the "thistle" belongs, is on the shores of the Mediterranean, and from thence "thistles" and clover were probably introduced by the Spaniards. And they not only found the soil and climate suitable, but a still greater point in their favor, they found the ground very scantily occupied by native vegetation.

There had not been time to plant this corner of the world's farm thoroughly, for it had been under water until comparatively recent times—recent, geologically speaking, that is. And when it became dry land there were few plants and no trees at hand to colonize it.

There was abundant vegetation to the north, however, and that of the most luxuriant kind, and most of the early colonists came from there. But they were too delicate to bear well the change to such much cooler regions, and only a few managed to settle down and really flourish; so that when the Europeans came, strong and vigorous, they soon overpowered these previous colonists, which had but scantily occupied the ground, and themselves grew in a rampant manner. Any delicate new-comers arriving after such sturdy emigrants as these would naturally have no chance at all.

Plants may find a vacant or almost vacant spot, and they may like the soil, and even the climate, but if they are dependent upon any particular insect for fertilization they will not be able to perfect their seed without it; and if they cannot do this they can never become naturalized, and must needs in most cases die out.

Of plants which require help, those are most likely to prosper whose blossoms are least peculiar in shape, and most accessible. Tubular blossoms, such even as the

common clovers, require insects with trunks of some length, because their nectar is so deeply hidden that none but these can reach it. And insects do not visit flowers where there is nothing to be gained.

Composite flowers, such as the daisy, dandelion, camomile, groundsel, and many others whose blossoms grow together in flat heads, are easily fertilized by almost any insects; and what with this advantage, and the further one that so many of the family have downy seeds easily carried by the wind, composites are among the most thriving and successful emigrants.

QUESTIONS FOR REVIEW

1. What questions, difficult to answer, are suggested by the seeds of various plants?
2. What interesting cases have been known of seeds which kept their life for hundreds of years?
3. What truth is suggested by the fact that the wild orchis does not increase?
4. What difficulties may plants encounter in new localities?
5. What may happen to seeds before they even begin to grow?
6. How do some seeds bury themselves?
7. What difficulties does the Brazil-nut encounter?
8. What change was brought about by cattle in New South Wales?
9. Give examples of seeds helped by being scorched, boiled, and soaked.
10. Why have European seeds flourished in the United States?
11. How do Western plants migrate?
12. What fact is illustrated by the Pampas district of South America?
13. Why are composites apt to be successful emigrants?

CHAPTER XX

FRIENDS AND FOES

From one point of view all animals, with the exception of a few insects, may be looked upon as enemies of the plant-world, since they either themselves feed upon plants, or live on others who do. But this would be a very partial view of the matter, even where the destruction is complete; for it is a positive benefit to the race that the greater number of seedlings, as well as seeds, should be devoured, or otherwise removed, since without this thinning of their numbers none could come to perfection.

Linnæus calculated that any one annual which produced but two perfect seeds—its descendants doing the same every year—would have increased to a million in the course of twenty years. Now all annuals do considerably more than this as a rule; and as they do not increase at an alarming rate, it is evident that their existence must in many instances be cut short, at one time or other of their career.

Plants have many and various enemies which attack them at different stages of their lives, but it is chiefly while they are seedlings that they are altogether exterminated, as they often are wholesale. Out of three hundred and fifty-seven seedling weeds growing together without any crowding in a small plot of ground, Mr. Darwin found that two hundred and ninety-five were destroyed, mainly by slugs and insects.

From the point of view of the destroyed—the victims—these creatures were undoubtedly foes; but from that of the survivors they were as certainly friends, for the latter would grow up all the more vigorous for having plenty of space.

But if slugs and insects were allowed to multiply without check, they would become foes and nothing else, and would end by eating up every green thing. There are checks upon their increase, however; and besides this, many plants are to some extent protected against them, as otherwise certain species might be exterminated altogether.

Plants like the grasses, which bear vast quantities of seed, are protected by their very numbers, and can well afford to be eaten, if but a small proportion be allowed to perfect and disperse their seed; but others, less prolific, are guarded in various ways, being made either disagreeable or difficult of approach.

The whole of the Gentian order, for example, are so extremely bitter, that they are seldom touched even by caterpillars; and the Eschscholtzia, which is of another order, is also so intensely bitter as to be more avoided by slugs and the like than any other plant, it is said. Even Eschscholtzias are, however, a good deal bitten at times, probably by earwigs, but this may be owing to drought and consequent scarcity of vegetable matter, as it is not a common occurrence. It is at least something to be proof against certain classes of enemies; and no plants are defended against all, since they are intended to be eaten, though not exterminated.

The bark of oaks, elms, and willows is made sufficiently unpleasant to most animals by the presence of tannin; and

ferns contain so much of this that few animals care to eat them, though they have their own particular caterpillars.

Many plants are not merely disagreeable, but even poisonous to mammals, though birds may eat the seeds, and insects the leaves, with impunity; and others again are of such a biting flavor as to raise blisters on the tongue or skin. Some members of the buttercup family are of this acrid nature, and the buttercup itself is said to be avoided by cattle; but on the other hand, the deadly nightshade, which is fatal to man, is eaten with impunity by the rabbit.

The Asclepias gigantea of the desert is so deadly that the least drop of the poisonous milk contained in its leaves and stem causes total blindness if it touches the eye; and even those who cut the plant for fire-wood must beware of so much as touching their eyes afterwards, since a merely accidental rub may deprive them of sight.

One would suppose, therefore, that the Asclepias was so amply protected as to have no enemy at all; yet there is one upon which its deadliness makes no impression whatever; and this, the goat, devours it greedily, though all other animals refuse and avoid it.

Goats are indeed the most omnivorous and most destructive of animals, and very few plants, or even trees, are safe from them. Neither the thorns of the prickly pear nor the flinty "needles" 'of young pines and firs afford any sufficient protection against them; and yet even the goat has its preferences, and is said to refuse lettuce, while it will eat cabbage.

Probably each plant has its own appropriate enemy—really a friend to the race—whose office it is to check its

undue multiplication. And one reason why plants introduced into other lands sometimes run riot there, and even extirpate the natives, is just this, that they are foreigners, and that there is at first no animal to keep them within bounds. If there had been some common bird to eat the seeds of the wild artichoke or "thistle," for instance, when first it reached South America, it could not have gained the upper hand so entirely as it has done. At present the plant itself is eaten to some extent by horses and mules, but only when other forage is scarce, as its spiny leaves are a great protection, and make it actually formidable to most quadrupeds. Goats might manage it, but otherwise it seems that birds are what are wanted to keep it in check. Eventually, however, man may prove to be its "appropriate enemy," and will cut and stack it, as he has begun to do with its cousin, the Scotch thistle, in Victoria, which proves excellent winter food for cows, when thus treated, as the spines lose their stiffness when dried.

Foreign plants are, however, sometimes at a disadvantage when introduced into a new country, as they may meet with enemies unknown in their native land, and against which, therefore, they are undefended. But generally speaking, foreigners are much let alone at first, for most animals are suspicious of anything new and unfamiliar; and nearly all, especially of the mammalia, far surpass us in keenness of scent. They "live in a world of odors," most of them with their noses near the ground, always on the *qui vive* to notice anything strange; and generally speaking, what is new and strange that they mistrust and avoid.

When they have attained a fair size most plants can

well afford to have some of their leaves eaten; but if no blossoms are left the plant dies without successors, and this, in many cases at least, is not to be desired. Accordingly we find that, as a rule, blossoms are avoided by all animals, including even caterpillars, which would rather die of hunger than eat the blossom of the very plant whose leaves are their favorite food. Earwigs, indeed, are less particular, and are given to biting dahlias; and whatever wild rabbits may do, tame ones often begin with the blossom of poppies and succory, as if it were a choice morsel.

Plants are protected against indiscriminate consumption in a variety of ways: by being unpleasant in flavor or poisonous, by the toughness and hardness of their foliage, by prickles and by thorns, sometimes of formidable size, and by hairs, whether sticky or stinging.

Prickles and thorns are among the most efficient guards a plant can have, and are often positively formidable weapons of defense. One has only to think of the strong, stout thorns of the rose, and the long, sharp ones of the gooseberry-bush, to realize that it would be dangerous for any animal to attempt to make a meal of them. The sharp little prickles of the raspberry, too, must make it, one would think, anything but pleasant eating to most creatures, though donkeys will munch raspberry-canes as well as thistles.

But small thorns, sharply as they can wound, are a mere trifle compared with those which protect many foreign plants and trees until they have grown beyond the reach of cattle. Even the tough hide of the elephant is not proof against the "jungle nail," or "elephant thorn," an acacia, whose lancet-like spines—which frequently

grow not singly, but in branching clusters—make any forest where it abounds absolutely impassable.

The buffalo thorn, or bull's horn acacia, is interesting in another way. Its trunk and branches are beset by strong thorns two or three inches long and as sharp as needles, which grow in pairs, and are shaped just like horns. But as if this were not enough to insure its safety, the tree maintains as well a standing army, which keeps off all aggressors, large and small, at least during the wet season, for then every thorn is tenanted by ants, which rush out and sting severely any animal venturing to touch the tree.

Caterpillars, which might make their way between the thorns without injury, have no chance against the ants, and even their own rapacious relations, the leaf-cutting ants, are completely baffled.

The ants of the buffalo thorn are not to be found in the forest, or indeed anywhere except on this particular acacia, which belongs especially to the dry plains or savannahs of Central America. When the "horns" are first put forth they are filled with a soft, sweetish pulp, which the ants hollow out, burrowing between the partition which separates them, and thus making a single dwelling of each pair. The thorns do not suffer in any way from this treatment, and continue to grow until they have reached their full size.

But the ants do not frequent the trees for the sake of comfortable lodgings merely. They want, and find, food as well. At the base of each pair of young leaflets there is a gland, which contains a liquid something like honey: and besides this, the young leaves bear what are described as "minute golden pears," small, sweet protuberances,

which ripen in succession, and need constant examination. These two delicacies, their sole food, the ants are always ready to defend, and during the wet season hundreds of them may be seen running about on the young leaves, which are thus kept clear of all enemies for some time after they unfold.

A very different ant, the parasol, or leaf-cutting ant, is one of the worst enemies of vegetation in tropical America, where it is called the curse of the country, owing to the damage which it inflicts on the crops. It may be a friend in disguise to the wild crops, by preventing their too great increase, and its services in the past in burrowing and tunneling and in adding to the organic matter of the soil must not be forgotten; but at the present day the farmer can hardly look upon it as other than an enemy. It is the cultivated plants of foreign origin which it especially attacks, for very many of the natives are protected against it in one way or other, while the foreigners are undefended—a good example of the risks sometimes run in this way by colonists.

The Indians defend their trees by a very simple device, that of fastening thick wisps of grass with the sharp points turned downwards round their stems. The multitude of points quite baffles the ants, and prevents their climbing farther up. Orange-growers plant their young trees in the center of ring-shaped earthen vessels, which are kept filled with water, and answer one of the purposes of the natural "basins" of the teasel, and other similar plants.

In some parts of America orange-trees have run wild, and have formed thickets, in spite of the ants; but generally speaking, all the species of the citron family—the

orange, lemon, etc.—except the lime, would be very quickly destroyed if they were left without the help and protection of man. The lime has run wild, and seems to be less liked by the ants than the orange and lemon, whose leaves they "cut up into sixpences" when they have the opportunity, leaving nothing but rags behind them. They are terrible enemies to young plantations, nurseries, and gardens; but they greatly fear the small ants which protect certain plants.

The agricultural ant of Texas occupies a different position from that of the leaf-cutter, for she is really an agriculturist on her own account, and the only one in the animal world, so far as we know. She is no more an enemy to vegetation, therefore, than the farmer who cuts down "bush" that he may grow wheat, for she does a precisely similar thing.

It is unfortunate for the farmer, of course, when her "bush" chances to be his corn or sweet potatoes, which she cuts down as ruthlessly as he does scrub; or when she decides that his young fruit-trees must be stripped of their leaves because they keep off too much of the sunshine from her domain. But she does not plunder his crops for food, and she does grow and tend and reap crops of her own as regularly and carefully as he does himself.

For this purpose, at least partly, she makes circular clearings some ten or twelve feet in diameter, sometimes in rough, wild pasture, sometimes in the middle of the farmer's fields; and she clears away his cotton or corn just as impartially as she does the weeds, for to her they are weeds. Considering her size, her labors are truly herculean, for she cuts through, with her teeth, stems as thick as a thumb; and by dint of sawing, twisting, pull-

ing, biting, she clears everything away, no matter how rank the growth. And this is not all, for the space is not only cleared once, but kept clear till the "ant-corn" has ripened—a matter involving no small labor where it is surrounded by a dense growth of weeds always ready to encroach.

The crop consists of a tall, yellowish grass, and not so much as a blade of any other species is allowed among it. It ripens about the end of June, when the seed is cut from the stalk and carefully stored. That which falls of itself to the ground is not harvested, and it is probably from this that the next year's crop springs, though some have declared that the ants actually sow as well as reap. Harvest over, the dry stubble is cut and cleared away, and weeds are left to grow as they will during winter, the work of cutting them down beginning vigorously again in spring.

These ants live chiefly on grass seeds, which they gather from a distance as well as from the home crop; but though they do not steal food from the farmer, they inflict much injury on his fields, and destroy many an acre of produce, no amount of plowing being sufficient to drive them away.

We cannot attempt any description of the devastations caused by locusts, one of whom is reported by Mahomet to have remarked, "We are the army of the great God; we produce ninety-nine eggs. If the hundred were complete, we should consume the whole earth and all that is in it." Nor can we tell of the ravages of the American crickets, which eat up a whole crop of maize in a night; or of the caterpillars, which would completely destroy the tobacco plantations if not constantly picked off leaf by

leaf; or of the minute beetles, whose grubs, penetrating between wood and bark, destroyed in 1780 and the following years a million fir-trees in the Harz Mountains and Switzerland, fifty thousand trees, chiefly oaks, more recently in the Bois de Vincennes, and are causing avenues of fine elms to disappear in the north of France. Green fly, scale insects, slugs, wireworm, grubs, and the various other plagues known to the gardener and agriculturist must also be passed over, and we must go on to consider by what natural means these various creatures are kept in check and prevented from becoming positive enemies to all vegetation, instead of merely thinning the ranks, to the advantage of the survivors.

For when one reads of flights of butterflies which take days and weeks to pass, of armies of caterpillars which stop the progress of railway trains, and of dense clouds of locusts several miles long, it is quite evident that unless their increase were restricted by some very efficient means they would all more than justify the locust's boast, and leave not so much as a blade of grass.

Man is utterly unable to cope with them by any means at his present disposal, and when he interferes with nature's way of keeping them within bounds, he learns by hard experience his own utter helplessness, and often not till then.

In the Middle Ages people seem to have had the feeling that they ought to be able to control grubs and the like by the mere word of command, and the chroniclers of the time often give reports of the lawsuits instituted against these creatures. In 1479, for example, the canton of Berne was troubled with such an overwhelming plague of grubs that the council petitioned the archbishop of Lau-

sanne to banish them, and the priests were authorized by him to do so. In accordance with the usual custom on these occasions, advocates were appointed for both parties—the grubs and the people. A written summons was issued; the grubs were cited to appear, and some were brought into court; but they were not fairly treated, as the advocate assigned to them was no longer living, and judgment was given against them in these terms: "We, the archbishop of Lausanne, condemn and excommunicate ye obnoxious worms and grubs, that nothing shall be left of ye except such parts as can be useful to man."

No steps seem to have been taken, however, to give effect to the sentence, and the grubs obstinately ignored it.

But if the council could have imported a few hundreds of small birds, they would most likely have been quickly rid of the plague; for these, and these alone, are the natural and most effectual provision for keeping the numbers of grubs, caterpillars, and the like within their proper limits.

QUESTIONS FOR REVIEW

1. Show how different plants have their appropriate enemies.
2. What advantages have foreign plants?
3. In what different ways do plants protect themselves?
4. What peculiarity has the bull's horn acacia?
5. By what means are ants prevented from injuring various kinds of vegetation?
6. Describe the habits of the agricultural ant.
7. What surprising instances can be given of the ravages of insects?

CHAPTER XXI

NATURE'S MILITIA

"If nature's militia, the army of birds, be killed, it will be impossible to find a substitute for their faithful guardianship."

"Birds are nature's soldiers, and keep in subjection the inferior animals. Their other uses are scarcely worthy of notice compared with their labors in the destruction of insects."

Wise words, which cannot be too often insisted on; for though we are beginning to wake up to the immense value of the feathered tribes as guardians of our fields, we are still only beginning; and unfortunately, farmers and gardeners, the very persons most interested, are precisely those whom it is most difficult to arouse.

They know well enough, of course, that insects, generally speaking, are their enemies; but they do not yet recognize, as they ought, that the birds are their friends, who, if only let alone, would save the crops from these marauders.

A plague of grubs finds us, in fact, just as helpless as our forefathers in the Middle Ages, and almost more hopeless, for we no longer believe in trying to "banish" our enemies, and we have not yet discovered any more effectual means of dealing with them. When the infliction comes, we talk mysteriously of "blight" and "weather"; and it seldom occurs to us to connect the increase of grubs

with the destruction of birds, even though we must know, as a matter of fact, that the latter live mainly upon the former, and that therefore for every bird killed, so many grubs must be left alive.

It is now some thirty years since piteous complaints were rife in Germany and Switzerland of the alarming increase in the number of destructive insects, which made their appearance in overwhelming swarms, and inflicted the greatest injury on the fields. And at last it occurred to the authorities that insects had multiplied because birds had to so large an extent vanished. The "militia" had, in fact, been either killed off or driven away; they had been destroyed in the most insane manner, in ignorance and sheer wantonness; and also they had been "improved" away by the spread of agriculture. In whatsoever way it had come to pass, the result was the same—there were fewer birds, there were more grubs; and as the latter increase much more rapidly than the former, the prospect was a dismal one. The land was being devoured.

And it was devoured, partly at least, because more had been taken into cultivation. For woods and thickets and groups of trees had been cut down to make way for fields; and land being precious, hedges were considered an unnecessary extravagance. There are, of course, still extensive woods and forests in Germany, but one may travel many a long mile without seeing any of the hedgerows with which he is familiar in England. The fields are for the most part one large expanse, without any bordering of trees or bushes.

But it is quite possible to be too thrifty. If every foot of land is occupied by crops, where are the birds to build their nests? Most of them need more shelter than is to

be found upon the ground, and if they cannot find it in one place they are obliged to look for it in another. If the farmer will not spare them a few trees and bushes, they are compelled to desert his fields and leave them unprotected.

But this is not all. Grubs as well as birds find shelter in the hedges; and not only shelter, but food. When the birds are driven away, therefore, the grubs are driven away, too; but, alas! while the birds migrate to a distance, the grubs are only driven out of the bushes and hedge-plants, where they are comparatively harmless, into fields, orchards, and gardens, where, in the absence of the "militia," they run riot as they will.

We see, indeed, the

> "Hedges all alive
> With birds and gnats, and large white butterflies,
> Which look as if the May-flower had caught life,
> And palpitated forth upon the wind."

We see; but perhaps we hardly realize that if the hedge be cut down its population will find quarters elsewhere; and that while the birds betake themselves to the nearest thicket, perhaps some distance off, the butterflies and moths will simply flit a few yards, many of them being quite content to supply their offspring with cultivated plants when they cannot get wild ones. Somewhere or other they must and will lay their eggs—if not in the hedgerow, then in the garden; and the grub of the white butterfly is, as we all know, able to make quite a decent living upon cabbage-leaves.

But this was not all, or nearly all. Not only had the grubs been driven into the fields, and the birds driven out of them, but the latter had been killed wholesale. Gov-

ernment keepers were actually under orders to destroy the woodpeckers, whose special office it is to rid the trees of beetle-grubs, and the cuckoos, which devour the hairy caterpillars which no other birds will touch, and so on.

And the Germans have not been the only, or even the chief, offenders. They have killed their own birds, and have suffered for it. But the Italians have done worse; for they have waged deadly war upon the birds which are the common property of Europe. They have a perfect mania for slaughtering small, insect-eating birds, and unhappily they have special opportunities of gratifying it, as large flocks of migrants pass through this, to them inhospitable, land every year on their way to and from the south. Considering the way in which they were received, one wonders why they did not choose some other route; but the force of habit seems to be too stiong for them, and their ranks have been thinned year after year in the most fatal manner. Not even the swallows were allowed to pass unmolested; for to catch them, by floating hooks baited with flies in the air, seems to have been considered a particularly fascinating pastime.

For months the chief delight of the population was in catching birds, and several million were killed regularly each autumn in the neighborhood of Verona alone. Larks are among the most useful of the insect-eating birds, and so entirely harmless that even the farmer has no fault to find with them. Yet neither their usefulness nor their harmlessness were sufficient to save them from persecution. Unluckily for themselves, and we may add, for Europe, they had chosen Sicily as one of the places at which to break their journey, and they could hardly have done worse. The Sicilians knew when to expect them, for they

came regularly every autumn, nearly a million arriving daily for ten days, and they gave them a warm reception. Hundreds of the population went out to meet them, armed with guns, and there was a regular battue. How many were slain history does not say, but the numbers must have been very great. They did not die unavenged, however; for every lark killed left so many more insects to ravage the crops; and when people woke up enough to put two and two together, and to connect the plagues of insects with the destruction of the "militia" which should have kept them under, measures were taken to check the persecution.

To some extent birds are now protected in Europe; but we do not seem to have learned our lesson even yet, for a cry that the birds are being exterminated is now making itself heard in Asia, Africa, and America. The war carried on against them in India is already having very serious results; the swamps and marshes of Florida are being depopulated; Guinea is being despoiled of its birds of paradise, and birds of bright plumage are becoming more and more rare everywhere all over the world.

And why all this slaughter? Not because there is a famine in the land, and the birds are needed for food; not even for the sake of "sport"; but because the fashionable women of Paris, London, and Vienna require the sacrifice of at least thirty million birds every year, that they may decorate themselves with feathers.

In India, which furnishes hundreds of thousands of skins every year, insect life is rampant beyond anything that we have experience of, and is "only kept within bounds by the utmost effort of all the checks provided by nature." The "patient, unpaid labor of the useful small

birds'' is the one only remedy for the insect epidemics to which the empire is liable, and it is sheer madness to allow them to be killed off.

We must hope that the ''Indian Wild Birds' Protection Act'' will at least check the slaughter, for if it be allowed to go on, it can have but one result, and the birds will be avenged here, as they have already been in Europe. When once they are gone, no artificial substitutes can by any possibility make up for them. One may syringe the fruit-trees, cover the gooseberry-bushes with road-dust, pay regiments of school-children to gather grubs by the quart, try in fact all the various expedients which have ever been resorted to, and yet find in the end that it is simply impossible to overtake the damage caused by the absence of the birds, with their marvellously keen sight and extraordinary appetites.

Let us consider for a moment one single fact. Mr. Darwin found that scarcely more than a sixth part of his seedlings survived the attacks of slugs, snails, and insects. But what does this mean? Only this, that if the numbers of the enemy had been increased by so much as a sixth, there would have been no seedlings left alive at all.

Take, for example, the common house-fly, one of which is said to have twenty-one million descendants in the course of a single summer, or would have, if all were allowed to live. That we do not have a yearly plague of flies is due solely to the vigilance of the birds.

And what quantities they devour! for their digestion is very rapid, and whereas human beings require only a few ounces of dry food a day, they swallow a quantity which is equal to their own weight. Think of it! the weight of a bird in insects; green flies, for instance.

One redstart, kept in a room, has been known to eat six hundred flies in an hour; and one blackcap has cleared about two thousand greenflies from the rose-trees in a greenhouse in the course of a few hours.

The titmouse is another most active little bird, constantly engaged in the hunt for food, creeping into rolled-up leaves, and devouring by the thousand eggs which would produce many more hairy caterpillars than the cuckoos could dispose of.

The wren, like the titmouse, is perpetually eating, and feeds her young thirty-six times in an hour; the cuckoo, too, eats all day long, every five minutes or so, and devours about one hundred and seventy good-sized caterpillars in the day; and as each of these caterpillars, if allowed to reach the butterfly state, might lay some five hundred eggs, every cuckoo rids us of a possible eighty-five thousand odd caterpillars daily!

And the work goes on vigorously in winter, as well as in spring and in summer, for with all the vigilance of the birds, caterpillars and grubs innumerable escape and pass into the chrysalis state, which they spend—as much of it as they are allowed—in cracks and crannies, in sheltered nooks, on twigs and trunks of trees, on palings and walls, and in the ground. These supply food to the many insect-eating birds which do not migrate; and but for the unceasing labors of these stay-at-homes we should be overrun with insects in the spring, in spite of all that is done in the summer; for each chrysalis devoured saves us from some hundreds of grubs or caterpillars later on.

If any one needs proof of what would certainly follow the extermination of the birds, he need only look at the island of Jamaica, where they are at present very scarce,

having been killed off, chiefly to adorn women's bonnets. It must be remembered, too, that while birds multiply only by tens, insects increase by hundreds, by thousands, and by tens of thousands, in a single season, so that although the birds are now protected in Jamaica it will be long before the loss is made good. Meantime they are terribly avenged; for the island suffers from a disgusting and grievous plague of ticks imported with cattle, which swarm upon every leaf and blade of grass, except on the higher hills.

To make matters worse, too, the mongoose was imported a few years ago, and like sundry other importations, has proved a dismal failure. The idea was that it would kill off the rats which so swarmed in the sugar-plantations as to be a great nuisance to the planters. And the mongoose began well; but when its numbers had increased, as they did enormously, it began to vary its diet of rats by eating the eggs of such birds as build on the ground, and then it went on to eat the birds themselves, and even poultry, besides killing off all the lizards and snakes, which were not only quite harmless, but most useful as insect-eaters. In one way and another, the ticks were thus delivered from their natural enemies, and now have things pretty much their own way, and seem likely to have for some time to come.

However, there are probably few people in the present day who would seriously dispute the value of such birds as live upon insects only. It is when we come to mixed feeders, such as the sparrow and the crow, that opinions are divided.

A fierce battle rages round the sparrow. He is accused of stealing corn and fruit, and of heartlessly destroying

crocuses for the sake of the unformed seeds. In some districts he is persecuted without mercy and leads the life of an outlaw. Sparrow clubs, encouraged by the farmers, kill him by the thousand and destroy his nests.

That he is mischievous no one can deny, and that he sometimes does serious damage must be admitted even by his warmest admirers. But if we cannot have our crops without paying toll upon them, it seems better to share with the sparrow than lose all to the grub—the only choice, according to some, which lies before us.

The sparrow's friends, the naturalists, say that each sparrow actually saves a bushel of corn, for he himself lives for nine months of the year almost entirely on grubs, while his family eat absolutely nothing but insect food as long as they remain in the nest. One pair of sparrows, it is said, take four thousand three hundred grubs or other insects to their young in the course of a week; and that they are the deadly enemies of the cockchafers, which have done a million pounds' worth of damage to the crops in Normandy, is evident, for the wing-cases of seven hundred cockchafers have been found under a single nest.

Finally, we are told that caterpillars to the number of 354,375,000,000 are eaten by sparrows every year, and that while we see the damage which the sparrow does during three months of the year, we do not see how hard he works for us during the other nine, or what far greater damage he averts from us. We grudge his wages, in fact, simply because we do not understand how vast are his services.

But a few facts are worth many arguments. Let us see what has followed the expulsion of the sparrow in one or two cases. Frederick the Great of Prussia waged war

against the sparrow, and—he was defeated, ignominiously defeated, and he had the good sense to own it. The king liked cherries, and the birds liked them, too; and he gave orders that the sparrows should be driven away, exterminated, got rid of. And he was so well obeyed, that in two years' time there was not a sparrow left in the neighborhood. So far he was the victor, for he had certainly vanquished the birds; but he had overreached himself, for instead of having more cherries he had none!

There were no cherries at all that year; worse still, there was no fruit of any kind, but in its stead a hideous crop of caterpillars, which had stripped the trees of their leaves. Other birds besides sparrows, of course, eat caterpillars, but the means used to get rid of the sparrows had frightened these others away also. The orchards had been deprived of their guardians, and the enemy had taken possession, and before matters could be set right sparrows had to be imported, at considerable expense; for they would never, it is said, have returned of their own accord as they are not given to wandering.

Pigeons are the only birds which live on nothing but vegetable food; yet the wood-pigeon is now recognized as such a valuable servant in Belgium, from its habit of eating the seeds of the poppy, spurge, and others which no domestic animal can touch, that it is strictly preserved. Where such seeds are not to be had in sufficient quantities, no doubt the pigeon makes up for it by stealing peas and corn, but the Belgians seem to have made up their minds that it is better to run the risk of having to pay occasional toll to the pigeons than to have their crops choked with weeds.

A few words as to what in temperate latitudes may be

regarded, perhaps, as the farmer's three worst enemies—cockchafers, daddy-long-legs, and click-beetles or skip-jacks. It is in the grub state that most insects are chiefly mischievous, for this is their grand eating-time; eating is then their sole business, and they eat for their whole lives. For when they get their wings they usually want so little food, and that of such a kind that no one can grudge it them. A caterpillar eats leaves, for instance, and devours them greedily, whereas a butterfly takes but a sip of nectar, the loss of which is no injury to even the most delicate flower. Yet as the winged insects lay multitudes of eggs, they cannot be called harmless, and some few of them even do a good deal of eating on their own account. Cockchafers, for example, eat leaves, and sometimes strip whole woods, while their grubs devour roots. Daddy-long-leg grubs (turnip-fly) are equally destructive, and so terribly hardy that they thoroughly deserve their name of leather-jackets, for they are very little affected by weather, and may be frozen stiff, or lie under water for a couple of days, and yet be just as lively as ever afterwards. Insects, indeed, often take a great deal of killing, and will live through frosts, especially in the chrysalis-state, when the poor birds perish by hundreds.

As for the grub of the click-beetle, its very name is enough to make a farmer shudder, for, as the wire-worm, it is only too well known. For five whole years it remains a grub, eating all the time. And it will eat almost anything in the way of vegetable food, turnips as well as sprouting corn, or hops, and grass-roots as well as any of these. Where the young corn is strong, it will sometimes recover from having its first shoot eaten off just below the ground, and will even send up two or three shoots instead

of one; but when the plants are weak, as they often are on light, chalky soil, there the wire-worm destroys sometimes the half, and occasionally the whole, of a crop.

To help him in the perpetual war which has to be waged with these three special foes, the farmer has friends—the sparrow again, and the crow, jackdaw, magpie, jay, all the smaller birds of prey, in fact, and many of the larger; and besides these, he has the stoat, weasel, mole, and hedgehog, which last, though much persecuted, is most useful, and quite inoffensive.

The battle about the crow is only less fierce than that about the sparrow, but while it is no doubt true that he does uproot some plants in his search for grubs, that he does steal a little corn, and that, when insects are scarce, or crows too many, he even attacks the crops, still, where crows are poisoned, wire-worm increases and crops fail. One crow will have as many as three dozen daddy-grubs or click-beetles in its crop at once, and the birds go over the ground yard by yard in the most systematic manner, working from early dawn till evening, each bird catching, it is said, at least fifty wire-worms in the day.

In some parts of the country the crows are often joined at their work in the furrows by large flocks of gulls, titmice, and others, which appear when plowing begins, and go away when the furrows are cleared, without taking any pay from the farmer, except in the shape of the insect food which he is glad to be rid of.

Other very useful birds, which must be passed over with a mere mention, are the various species of plover, the partridge, and the pheasant—a couple of which will eat fifteen hundred wire-worms at a meal—the thrush and the landrail, both of which clear the fields of snails and

slugs, and the swallow, martin, and swift, without whom the air would be so choked with flies as to be simply unbreathable.

So much, then, for the services, the incalculable and indispensable services, of the "militia." We have seen something of these, and we have seen, too, how surely punishment has followed where the birds have been exterminated; but there is a word or two to be said on the other side of the question.

It is very rash for man to interfere with nature by exterminating any one class of the laborers employed, whether in the tilling or in the protection of the fields, cultivated or uncultivated; but at the same time, it is hardly less rash for him to interfere in the other direction, and to encourage these same laborers overmuch; or even, because they are found useful in one part of the world, to conclude hastily that they must be equally useful in another.

Thistles do not overwhelm us and swamp other vegetation in Europe; but he was a very rash man who imported a sack of thistle-seed into South America and scattered it broadcast about Valparaiso, with an idea of providing useful fodder for cattle! The thistle took to the soil and climate amazingly, and having nothing to check its increase, as it has at home, quickly spread over large tracts of country, to the great inconvenience of the cultivators.

Then, some one may be inclined to say, why not import birds to eat the seed? But things in nature are so exactly balanced that even this step would probably be found to have its disadvantages, and possibly the birds might turn out to be even worse than the thistles. The sparrows imported into the United States, for instance, and at first

petted and made much of, have so thriven and multiplied that they are now a pest, and generally hated. But the mischief is done, and is not to be so easily undone. They, like the thistles, have had things their own way, for as there were no sparrows in these parts before, naturally no special checks to their undue multiplication had been provided.

The natural checks provided for keeping the small birds in their proper place are the birds of prey; and these—many of the larger, and all the smaller—not only kill small birds for their own eating, but feed their young entirely upon beetles, grubs, caterpillars, flies, slugs, snails, and the various insects which attack the green things. Many of them, too, hunt by night, and so destroy the night-flying moths and beetles which escape other birds.

Yet birds of prey, especially owls and hawks, are relentlessly persecuted by farmers and keepers, because they occasionally steal a young chicken, or—more heinous offense still—young pheasants and partridges, and perhaps yet more often they are killed because it is the fashion to kill them.

But even owls and hawks have their avengers. Sparrows, multiplied to excess, take to thieving, and commit great depredations in the fields; and still worse are the plagues of mice, which mar the land.

In Scotland and the north of England there has been a great outcry of late against the swarms of mice and rats which waste the fields and rob the barns, doing far more damage than the sparrows. But why this increase in sparrows and mice? Because the owls, hawks, stoats, and weasels have been killed off. Just that, and nothing else.

LONG-EARED OWL BRINGING FIELD-MICE TO HER YOUNG

Owls are the very best mousers possible—better than the best cats. One pair of owls have been seen to take as many as eleven mice to their nest in the course of a single evening. Ravens, crows, hawks, magpies, and jays all hunt mice, as well as cockchafers and other insects, as already said; and the young of the brown owl are fed with anything, from snails even to kittens and puppies. But the young of the barn-owl require a steady supply of fresh mice, and she herself makes mice almost her sole diet, so that she benefits not only corn but clover. For if it is true that the crop of clover-seed depends to a great extent upon the number of cats in the neighborhood, surely the presence or absence of those grand mousers, the owls, must make at least as much difference to it. For mice are very much addicted to eating humble-bees, as well as corn; and as the common purple clover is fertilized by humble-bees only, there can be no seed where humble-bees are wanting, which they certainly would be if mice were allowed to multiply unchecked.

In America, birds of prey are comparatively rare; not because they have been killed off, as in England, but because nature had not provided them—a very different matter. But now that the English sparrow has made himself unpleasantly obtrusive, hawks are being imported as the only likely means of quelling him. Why hawks instead of owls is not evident, but it will be interesting to watch the result of this second experiment; for if the hawks in their turn should increase to excess they might prove even worse than sparrows.

In some parts of the world the balance of animal life established by nature is very curious, and any interference with it is attended by danger. In some districts in India,

for instance, the tiger is as useful to the farmer as owl and hawk are here. If he kills off the tigers, as his English brother kills the birds of prey, then the deer multiply and eat his crops; and on the other hand, if he kills off the deer, the tigers kill him, for even a tiger must live! so that on the whole he finds it better not to interfere.

Insects are, as a whole, such enemies of vegetation that we are apt to condemn them in a body. Yet besides the many which convey pollen there are a few others which deserve honorable mention, and even the name of friends. These few are positive benefactors, for they leave the green things alone themselves and prey upon other mischievous insects.

Among these insect-friends is the lady-bird, to whom, as an American writer says, "we should take off our hats," for it destroys those terrible pests, thrips and greenflies.

Wasps carry off flies and caterpillars to feed their young grubs; and some species of ichneumon-fly deposit their eggs in the chrysalides of moths and butterflies, as well as in grubs and caterpillars, thereby killing them. But of all insects, perhaps some of the beetles are the most useful, for both in the grub and in the winged state, they catch and devour living prey.

To sum up: without insects many plants would be unable to produce seed, and so must in time die out; without the small birds, insects would increase so much that all green things would be destroyed; and without the birds of prey to keep the number of small birds within bounds, not only would farming be quite impossible, but wild plants would also suffer; for when the insects were

devoured, or even very greatly reduced in numbers, the plants dependent upon them for help would be seedless, and the remainder would be so plundered of their seed by flocks of hungry birds, that little would be left for sowing.

Both insects and birds, then, are the enemies of vegetation when their numbers are multiplied to excess; but without them, there would be no vegetation at all.

QUESTIONS FOR REVIEW

1. Why do insects increase when land is over-cultivated?
2. Describe the destruction of birds in Italy.
3. How is the destruction of birds being felt in other places also?
4. Give illustrations of the extent to which birds destroy insects.
5. How has Jamaica suffered from the loss of birds?
6. What are the arguments in favor of the sparrow?
7. What valuable service is rendered by the wood-pigeon?
8. How does the crow help the farmer against some of his worst enemies?
9. What experiments in planting imported seeds have ended disastrously, and why?
10. How do birds of prey help the farmer?
11. What curious balance of animal life is to be found in India?
12. What insects are entitled to the farmer's special consideration?